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## ORIGINAL ARTICLES.

### I.—On *Didymograptus*, *Tetragraptus*, and *Phyllograptus*.

By Dr. Gerhard Holm,
Palæontologist to the Geological Survey of Sweden, Stockholm.

Translated from the original in Geol. Fören. i Stockholm Förhandl., Bd. XVII, Häft iii, No. 164, 1895, pp. 319–359. By G. L. Elles and E. M. R. Wood, Newnham College, Cambridge.

(PLATES XIII AND XIV.)

(*Continued from the October Number, page* 441.)

Didymograptus gibberulus, Nich.

Moberg, Nya Grapt. från Skåne, p. 345, pl. viii, figs. 3–7.

As has been previously indicated (see p. 439[1]), the conclusion might be drawn from Moberg's description and figures of this species, interpreted by the knowledge of the true structure of the *Didymograptus* polypary, that the structure of the proximal part could in no essential particulars be separated from that just described in *D. minutus*, Mut. Consequently the genus *Isograptus*, which was proposed by Moberg for the species in question, is not authorized—at least, as founded on any of the characters cited by Moberg. The differences between *Isograptus* and *Didymograptus*, to which latter genus the species is referred by Nicholson, ought to be, according to Moberg, that in *Didymograptus* "both stipes arise at somewhat different levels on the sicula," and that "each branch is itself bilaterally symmetrical"; whilst, on the contrary, in *Isograptus* the stipes should "arise bilaterally symmetrical from the sicula," and each branch is not itself bilaterally symmetrical. As we have seen above, in reality in *Didymograptus* the left stipe is not bilaterally symmetrical, and the symmetry in the right stipe is entirely the same as that which is described by Moberg in *Isograptus*, namely, obliquely near the base, because the stipes do not arise from the side of the sicula, but from the "connecting" canal.

No one believes for a moment that the presence of symmetry in stipes is a distinction. The same is also the case as regards the point of origin of the stipes. As has been shown above, the stipe arises in *Didymograptus* from a point on the left side of the sicula, and this is, therefore, the apparent point of origin of the right stipe from the right side of the sicula, as is believed by Moberg, and which, as has been previously shown, lies at a different level to that

[1] The reference in the October Number, p. 439, to Pl. XIV is an error; it should be to Pl. XIII.—Edit. Geol. Mag.

of the left stipe. It follows from Moberg's description that the relation is completely the same in *Isograptus*, as we shall see.

According to Moberg, whose material consisted entirely of much compressed specimens in shale, the impressions in the shale of the two sides of the polypary present "as regards the proximal part" (including the sicula) "a somewhat different appearance." On the one side (dorsal side of Moberg) the "sicula," according to Moberg's interpretation, would be divided longitudinally from the middle, and would form "two similar primordial thecæ grown together along their whole length," except near the apertures. To each side of the "sicula" a theca is attached, and grows with it for the whole of its length. Again, on the opposite side of the polypary (ventral side of Moberg) no such division in the proximal part of the sicula has been observed, and the "sicula" passes up on the dorsal side into two lateral thecæ, between which the divided apertural part of the sicula (primordial thecæ) is visible.

On comparing the figures and descriptions with those of *D. minutus*, Mut., it is clear that figs. 3 and 7*a* represent the sicula side; to fig. 7*b* and the remaining figures there is no reference, but fig. 5, and probably also fig. 4, represent the anti-sicula side with the connecting canal, which Moberg regards as a longitudinally divided sicula ("primordial thecæ") consisting of the sicula and the left theca, which latter, as in *Phyllograptus* and probably also in *Tetragraptus*, arises either at the apex of the sicula or immediately near thereto. It is clear that the partition wall between the true sicula and the left theca has not left any impression on the shale on the anti-sicula side, from the fact that it is concealed by the connecting canal, which forms on this side the proximal part of the primordial thecæ, and passes over on one side into the right theca, and on the other into the theca immediately succeeding the left theca. Although *Didymograptus gibberulus* differs from *D. minutus*, Mut., in the position on the sicula of the point of origin of the left theca, and agrees in this respect with *Phyllograptus angustifolius*, Hall, and *Tetragraptus Bigsbyi*, Hall, this is not a sufficient reason for retaining the genus *Isograptus*, for to judge from Törnquist's figures (Siljansområdets Grapt., I, pl. i, figs. 13, 14) the same would be the case in such a typical *Didymograptus* form as *D. decens*, Törnq. In this connection a question concerning the structure of *D. gibberulus* may be discussed. In the generic diagnosis and afterwards in the descriptions, Moberg characterizes *Isograptus* without reservation as a two-stiped form. In spite of this he seems, as far as I can understand, curiously enough, to contradict himself at the end of his descriptions, and inclined to accept the existence of four branches in the same, where, mentioning that "the apex of the sicula ends in a narrow tubular appendage, also observed in very young individuals, and that this appendage seems at a considerable distance from the sicula gradually to increase not inconsiderably in width," Moberg remarks—"Since this dilatation never takes place much outside the part of the appendage enclosed by the stipe, we should not run any risk in considering the appendage of the sicula

as part of a third branch (but which also might cause it to be supposed that still another branch existed, concealed in the rock)."

This appendage of the sicula is, however, quite certainly not a branch, but is formed by the unusually long, thread-like extension of the initial part of the sicula, as shown by an isolated specimen of my own from the grey glauconitic Vaginatenkalk near Hälludden, in Öland. The length of this in the specimens in question is over 7 mm., while the length of the branches is only 3 mm. It tapers gradually for the whole of its length towards the apex.

In connection with the genus *Didymograptus* may be mentioned a singular form of graptolite (Pl. XIII, Figs. 4–6), the figure of which is drawn from a damaged specimen, but subsequently two complete ones were obtained. The structure of the polypary is very simple, as besides the sicula it is formed only of the left theca and the connecting canal. A comparison between the figures of *D. minutus* (Mut.) and the present form, placed side by side and viewed in the same position, shows that in the latter the development of the parts mentioned is completely similar to that in *Didymograptus*, with the exception that from the bud of the sicula is developed besides the connecting canal only a left theca, but no left stipe. The connecting canal ends also near the right side of the sicula, without even giving origin to any right theca in case the connecting canal itself does not function as such. In the figured specimen the free apertural margin of the connecting canal projects slightly at its upper corner from the right side of the sicula. This, however, is not the case with the other two specimens. The sicula is provided with a true apertural spine, which originates in the periderm some distance behind the aperture, in the same way as the spines in *Diplograptus*, sp. (p. 438), and it appears to be of the same nature, but curiously enough, contrary to what is usually the case, it lies on the right side of the theca. The aperture of the left theca is turned straight out, and the lines of growth on the anti-sicula side show the same course as in the common canal—or the proximal part of the second theca on the left branch—in *D. minutus*, Mut. (Figs. 3 and 6).

That, however, the left theca is certainly terminal, and that consequently the left branch cannot develop, is clearly shown by the fact that the course of the growth-lines is everywhere quite regular, and parallel with the apertural margin; therefore no indication whatever of bud formation can be perceived on the proximal part of the left theca, either in this way or in surface relief. To this may be added what we have seen concerning the growth of the left branch in *D. minutus*, Mut.: the formation of the common canal and left theca takes place simultaneously, so that an interthecal wall cannot originate in a completed part of the stipe.

It has been observed in many cases that the same thing occurs at the distal end of the stipe: Pl. XIV, Figs. 6, 13, 14. It follows, therefore, that in the present form no left branch can be supposed to develop from the aperture of the left theca. The development of a right theca, or a right branch, from the connecting canal does

not seem to be in any way impossible. It is uncertain whether the Graptolite in question is only a young form or a distinct and fully developed species, the development of which ceased at this stage. How it comes about, I have not yet been able to decide. I have not found with it any species to which it could be referred. If a right branch should really be developed, the form might be referred to the genus *Azygograptus*, Nich. and Lapw., in which only one branch grows out from the free sicula. How and from what side of the sicula the branch arises in *Azygograptus*, does not definitely appear from the descriptions and figures given of the forms placed under it. Probably the present form is a transitional type between *Didymograptus* and *Azygograptus*.

### Genus Tetragraptus, Salter.

Hall[1] first described the proximal end in *Tetragraptus*: "In the Graptolites with four stipes the condition appears like that of two individuals of two-stiped forms, conjoined by a straight connecting process of greater or less extent, with the radicle point in the centre, though often obscurely marked. This connecting process is always destitute of cellules, and this with its divisions I have termed the funicle." Upon this statement is founded the presence of a tubular funicle uniting two sides of the polypary in forms with four or more stipes belonging to the Dichograptidæ. Almost all later authors, as, for example, Lapworth and Nicholson, have followed Hall in believing that the funicle is destitute of thecæ. I, however, have described the presence of a theca on each side of the sicula in the funicle in *Trochograptus diffusus*, Holm, whose proximal end is similar to that of *Tetragraptus*.

On these grounds, and in consideration of the many branched Dichograptidæ being embedded in shale, and therefore showing the thecæ of the central part of the polypary only in very exceptionally favourable cases, and as these thecæ are analogous to those in *Didymograptus* and other forms which are better exposed, I draw the conclusion that the funicle in many cases, if not always, was furnished with thecæ.

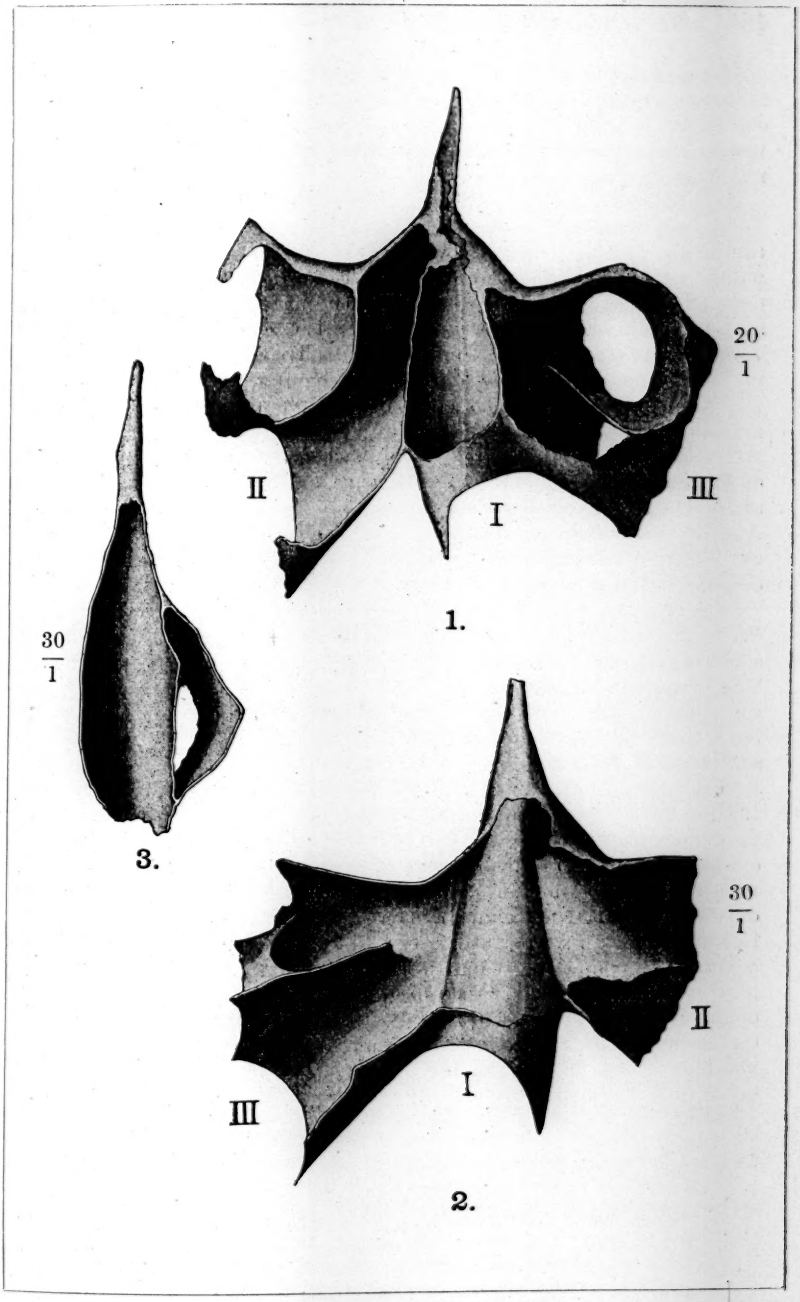
Curiously enough, Törnquist believes (Siljansområdets Grapt., i, p. 15) that "the expanded end of the sicula in Dichograptidæ which have more than two primary branches divides repeatedly into two, and thus without apparent border passes over into the theca-bearing polypary"; and it appears that on account of the supposed difference between *Didymograptus* and the remaining Dichograptidæ, he is inclined to separate the former as the type of a distinct family—Didymograptidæ.

A "funicle" has not been found in any Graptolite.

### Tetragraptus Bigsbyi, Hall. Pl. XIII, Figs. 9–16; Pl. XIV, Figs. 13–16; Figs. 1–3, p. 485.

This is the only form of *Tetragraptus* upon which I can offer any remarks.

[1] "Graptolites of the Quebec Group": Geol. Surv. Canada, dec. ii, 1865, p. 19.




*Tetragraptus Bigsbyi*, Hall.
[Reproduction of Taf. 12 in Dr. Holm's original paper.]

In consequence of the thickness of the periderm, I have not been fortunate enough to make it sufficiently transparent to show the course of the growth-lines. In most cases the specimens have been well preserved, with the exception of the apex of the sicula, which is nearly always crushed.

As I could not sacrifice my best preserved specimen for sectioning, I have not been able to distinguish the connecting opening between the sicula and left theca. Probably it is situated near the initial point, as in *Phyllograptus angustifolius* (Pl. XIV, Fig. 9). The development of the left theca, the connecting canal, the right theca, and the common canals, agrees in all essentials with that of *Didymograptus* (Pl. XIV, Figs. 13–16). These figures very clearly represent the *Didymograptus*-stage of a young specimen, in which the four branches of the second order have not yet begun to be formed.

The differences which are found between the *Didymograptus*-stage of *T. Bigsbyi* and that of *D. minutus*, Mut., may depend on the different angle of divergence of the stipes, and thus might be termed specific. A comparison between the latter and *T. fruticosus*, Hall, in which the angle of divergence is about the same, would certainly show complete correspondence in detail.

The foramen between the left theca and the connecting canal, with the left common canal, is visible from both the sicula and anti-sicula side (see Page-illustration, p. 485; Figs. 1 and 2 show examples). The detailed explanation of the figures gives an exhaustive description of the structure of the proximal part. Here only may be noticed the great width of the connecting canal in *T. Bigsbyi*, and how it forms along the sicula and left theca a raised projection on the anti-sicula side, in consequence of the situation of the foramen near the proximal end of the sicula; these are, therefore, here nearly completely concealed by, and embedded in, the connecting canal, in the interior of which they stand out in relief (see Page-illustration, Fig. 2). On the anti-sicula side, therefore, only the proximal apex and a narrow border of the sicula, and the left theca near its aperture, are visible; similarly, as in *Didymograptus* the connecting canal is somewhat oblique in relation to the long axis of the sicula. In consequence of a direct cleaving of the common canal by a vertical wall, the formation of two branches on each side of the connecting canal occurs, whereby there arise the four stipes of *Tetragraptus*.

Explanation of Page-illustration (see p. 485) printed in the text.

Tetragraptus Bigsbyi, Hall.

Fig. 1.—Proximal part from the sicula side, with the outer walls of the thecæ on this side removed so as to show the interior. The foramen between the sicula and left theca is not visible; that between the left theca and connecting canal is, however, shown on the left side; the anterior left branch is completely cut off, and of the posterior branch only the base remains, which arises from the common canal. On the right side, the right aperture of the connecting canal is indicated by the light, which, behind the sicula, through the foramen of the left theca and connecting canal, jointly falls into the background of the passage between the latter

and the common canal belonging to the right theca and right branch. The edge of the aperture in the right theca is injured, but the interthecal wall, which separates this from the anterior and posterior oldest thecæ of the right branch, is conspicuous. The anterior right branch is completely cleared away, and only a narrow border of the base of the posterior branch remains. The large opening shows the connection (common canal) between the two right branches. The projecting edge of the same is formed by a diaphragm-like intercalated lamella.—Enlarged 20 diameters.

Fig. 2.—The proximal part from the anti-sicula side, with the external walls of the connecting canal and the right theca removed in order to show the interior of the connecting canal and its relation to the common canal. The sicula, the apertural margin of which is perfect, appears in relief within the connecting canal; the same is the case with the left theca, the foramen of which touches the sicula wall. On the right side, the common canal for the left branch arises; on the left, that belonging to the right theca and right branch. Of the distal interthecal wall of the right theca the further part remains. The posterior right branch is completely removed, and only the base of the anterior remains, showing the curved inner edge of the interthecal wall between the first and second thecæ of the latter branch.—Enlarged 30 diameters.

Fig. 3.—Same specimen as Fig. 9, Pl. XIII. Longitudinal, vertical section of the sicula, on the sicula side of the polypary, showing the interior of a part of the left half of the sicula, and to the right of this a transverse section of the connecting canal. The foramen between the sicula and left theca is not visible, as it lies higher up within the part of the proximal end of the sicula, which has not been cut away.—Enlarged 30 diameters.

I = Sicula. II = Left theca. III = Right theca.

## Genus Phyllograptus, Hall.

No description of the structure of the proximal end, founded on actual or certain observations, is known. Hall thus summarizes, in his generic description, what he knows of the proximal end: "The whole supported on a slender radicle or combined in groups"; and he believed that, since the proximal end was provided with a "radicle," the majority were free in the same manner as in *Diplograptus*, whilst others were attached in groups to some support which bore them. In the figures only *P. typus*, Hall, is shown with a long cuneiform diminishing "radicle," which according to the description sometimes approaches half an inch in length. In the remaining three species the radicle is not visible, and it is described in the text as "minute" or "scarcely visible."

Lapworth, although he probably did not possess a good specimen of *Phyllograptus*, and therefore could not observe the development of the polypary, as early as 1873 rightly interpreted the same and the position of the sicula: "Polypary composite, being essentially a quadribrachiate monoprionidian polypary, whose branches coalesce by the whole of their dorsal surfaces; sicula embedded—the major extremity forming the proximal end of the adult polypary." The only observation on the sicula in *Phyllograptus* agreeing with the reality is that given by Törnquist (Siljan. Grapt., i, p. 20), where in *P. densus*, Törnq., he "believes himself to have observed a sicula with a jutting-up apex, between the most proximal thecal circle"; he adds, however, that this requires confirmation.

According to Törnquist, the thecæ should be situated in four

circles, and the four rows of thecæ are therefore of equal height. It follows from this that the genus *Phyllograptus* must be considered to have arisen from four branches, like those of a *Tetragraptus*, with their backs to each other, and that, since the sicula in *Tetragraptus* can branch dichotomously, the first thecæ of the branches ought to be of the same height.

We have seen above that the sicula does not branch either in *Tetragraptus* or in *Phyllograptus*, but that without this it gives origin to thecæ which, both in *Didymograptus* and *Diplograptus*, are developed from each other, and therefore occupy a different height in the polypary. Törnquist's supposition of a circular arrangement of the thecæ is therefore incorrect. The figures show that the arrangement changes conspicuously (Pl. XIV). This is due to the fact that the thecæ in different rows are separated by longitudinal septa, and are developed completely independently of each other, and therefore, since the height of the thecæ can change, any very regular arrangement is impossible.

Tullberg has done greater service than any other in emphasizing the near generic relationship between *Tetragraptus* and *Phyllograptus*. In his Classification of Graptolites, mainly based on that of Lapworth, which he justly takes to be the most natural, up-to-date, analytical table of the more important Graptolite genera, he has partially introduced some emendations. One of these is the suppression of the section Tetraprionidæ, originally proposed by Hopkinson for the genus *Phyllograptus* and accepted by Nicholson and Lapworth. Tullberg rightly places *Phyllograptus* with the Dichograptidæ as a close ally of *Tetragraptus*. Törnquist (Siljan. Grapt.) again returns to the old way, and has placed *Phyllograptus* in a separate family, Phyllograptidæ, allied to Dichograptidæ. *Tetragraptus* and *Phyllograptus* are therefore separated from each other by *Didymograptus*, which Törnquist places in the Dichograptidæ.

PHYLLOGRAPTUS ANGUSTIFOLIUS, Hall. Pl. XIV, Figs. 1–12.

By comparing the figures of *T. Bigsbyi*, Hall, and this species, the close agreement between them is quite evident, both in internal and external structure; with the necessary reservations due to the fact that the cœnosarcal threads of the four branches in the *Tetragraptus* polypary are in *Phyllograptus* disposed near each other, and instead of four independent periderm walls form a single, cruciform, four-winged, longitudinal septum. The oblique position of the sicula and of the proximal end of the left theca in relation to the median plane of the polypary stands out very conspicuously, as it lies completely revealed on the sicula side. Only the apertural edge of the sicula, which is turned, not only to the right side but also to the anti-sicula side, is visible on the latter. The connection between the sicula and the left theca takes place near the proximal end of the sicula: Pl. XIV, Fig. 9. The foramen between the left theca and the connecting canal has the same position as in *Tetragraptus*. From the right end of the connecting canal the right theca arises;

and immediately above, the common canals for both the right stipes of the polypary. Again, from the left end of the connecting canal arises only the common canal for the left stipes.

The three primordial thecæ, representing the *Didymograptus*-stage in *Phyllograptus*, occupy a somewhat oblique position in relation to the diagonals, which in the cross-section of the polypary are parallel with the thecal rows and describe a square : Pl. XIV, Fig. 5.

No trace of a virgula has been observed. The four wings in the longitudinal septum are rarely completely regular, but the form of the cross-section varies somewhat in longitudinal direction in the same specimen, without any definite rule (Pl. XIV, Fig. 8). Usually the wings are united two and two to a connecting lamina (Pl. XIV, Figs. 5, 11, and 12). The winged laminæ sometimes show a curved wrinkling. As an abnormality, there was observed in one specimen, on the anti-sicula side, a small supernumerary independent theca, probably arising from the connecting canal. A deformity observed in another specimen, was the presence of only three stipes. The proximal end of this is not preserved, therefore I cannot determine how the deficiency arose.

## EXPLANATION OF PLATE XIII.

### Didymograptus minutus, Törnq. Mut.

Figs. 1-3.—Proximal part of the polypary, showing the sicula, broken off near the apex, the left and right thecæ, and the connecting canal between them; also the proximal part of one other theca on each branch.—Enlarged 38 diameters.

Fig. 1.—Sicula side of the specimen, the rest of which is embedded in the rock; the cast with the periderm nearly entirely removed in order to show the walls, which appear as black lines, between the sicula on the one side and the left and right thecæ on the other side; also the incompleteness of the first-mentioned wall, by means of which the connection between the sicula and left theca is effected.

Fig. 2.—Anti-sicula side, isolated by means of acid, in reflected light, showing the roll-shaped connecting canal and the different shape of the left theca on this side to that on the sicula side, from which arises the inequality in the sides of the interthecal wall.

Fig. 3.—The same side, seen in transmitted light, so that the walls and the delicate growth-lines of the periderm are visible, showing also the limits of the thecæ, by the intersecting of the growth-lines at different foci of the microscope, and the connecting canal between the left and right thecæ. The wall of the canal next the right branch is somewhat broken, and here in consequence only the growth-lines of the sicula are seen.

Figs. 4-6.—An unknown Dichograptid, very young? specimen, consisting of only the sicula and left theca and the connecting canal, one corner of which projects beyond the sicula. On account of its small size and fragile nature, the proximal part of the sicula was considerably injured before the drawings were made. Slight fractures of the margins of the sicula and left theca have been restored in the figures.—Enlarged 22 diameters.

Fig. 4.—Sicula side, in direct light.

Fig. 5.—Anti-sicula side, in direct light.

Fig. 6.—Same side, in transmitted light, showing the growth-lines. The half of the periderm belonging to sicula side is ground off.

### Didymograptus gracilis, Törnq. Mut.

Figs. 7-8.—Proximal part of a developed specimen.—Enlarged 10 diameters.

Fig. 7.—Sicula side.

Fig. 8.—Anti-sicula side, showing the connecting canal.

TETRAGRAPTUS BIGSBYI, Hall.

FIGS. 9-12.—Proximal part of a specimen obliquely broken across the sicula and right theca—see Fig. 9—by the fracture of the rock. The pieces were cemented with Canada balsam, and both parts of the *Tetragraptus* specimen subsequently isolated.—Enlarged 6 diameters.

FIG. 9.—The more complete part, from the sicula side, showing the proximal part of the sicula, the left theca, the anterior left branch, and the passage between the connecting canal and the right theca.

FIG. 10.—From the left side, showing the left theca seen from the aperture, the proximal part of the sicula, and the anterior and posterior left branches.

FIG. 11.—From the anti-sicula side, showing the connecting canal and the sicula behind, the left and right thecæ, also the posterior left branch and the posterior right branch; in the latter the first theca is complete and the remaining ones show only the apertures.

FIG. 12.—From the proximal end, with the sicula side turned downwards, showing the apertures of the sicula, left and right thecæ, and the thecæ of the four branches.

FIG. 13.—Proximal part of another specimen lying in the rock, partly in relief, partly in impression. From the anti-sicula side. The connecting canal and the wall between that and the sicula have, however, remained in the counterpart, so that the smooth cast of the sicula appears uncovered. The left theca in impression, the right theca complete with fractured surface at the junction of the connecting canal.—Enlarged 6 diameters.

FIG. 14.—Another specimen. Proximal end, also lying in the rock, seen from anti-sicula side, showing the connecting canal. All the branches are broken off near their point of origin.—Enlarged 6 diameters.

FIG. 15.—Young specimen with posterior left branch complete. Anterior right branch injured near the apex, and both the remaining branches broken off near their point of origin. Anti-sicula side seen a little from the left, so that the aperture of the right theca appears, showing sicula, right theca, and connecting canal; the apertural part in the left theca is broken off. Isolated by means of acid.—Enlarged 6 diameters.

FIG. 16.—Isolated. Much injured specimen, showing sicula, left and right thecæ, and both anterior branches. Posterior right branch is missing, and only the first theca of the posterior left branch remains.—Enlarged 6 diameters.

## EXPLANATION OF PLATE XIV.

PHYLLOGRAPTUS ANGUSTIFOLIUS, Hall.

FIG. 1.—Sicula side, seen a little from the right, showing the cornet-shaped sicula, visible for the whole of its length, with the apertural margin turned somewhat to the right; to the left of this the left theca, also with its cornet-shaped proximal part lying along the left side of the sicula, but turning the apertural portion and aperture obliquely downwards to the left. To the right of the sicula, the right theca directed obliquely downwards, with the aperture turned to the right. Above this the thecæ lying in the plane of the paper and directed obliquely forwards; to the left the anterior left, and to the right the anterior right, series of thecæ. Behind the latter appears the outline of the posterior right series of thecæ.

FIG. 2.—Right side, seen a little from the left, showing the lowest of the right thecæ with the aperture turned forwards towards the spectator, and above it, to the left, the anterior, to the right the posterior, right series of thecæ. On the left side, behind the former, the apices of the anterior left series of thecæ appear, and behind the right theca the apex of the aperture of the sicula.

FIG. 3.—Anti-sicula side, seen somewhat from the right, showing the aperture of the sicula directed obliquely forwards to the left; to the left of this the right theca in profile, and to the right the left theca. Above this, to the left, the posterior right, and to the right the posterior left, series of thecæ. On the right side we get a glimpse behind of the outlines of the anterior left thecal series.

Fig. 4.—The left side, seen a little from the left. The aperture of the lowest of the left thecæ turned towards the spectator; above, to the right, the anterior, to the left the posterior, left thecal series. On the left side one gets a glimpse behind the left theca of the apertural part of the sicula, and behind the posterior left thecal series of the apices of the posterior right thecal series.

Fig. 5.—From the proximal end, with the sicula side turned upwards, showing in the middle the aperture and the oblique position of the sicula, and on each side of this the apertures of the left and right thecæ. The apertures of these three thecæ occupy almost one and the same plane, which forms an angle of about 40° with the cruciform plane of the thecal series. In this figure all the thecæ visible in the specimen in this position are drawn.—Enlarged 6 diameters.

Fig. 6.—Specimen with the anti-sicula side perfect, seen straight from this side, so that only the two posterior thecal series are visible. The sicula and the left and right thecæ appear in the same position as in Fig. 3. Isolated with acid.—Enlarged 4 diameters.

Fig. 7.—The interior of another incomplete specimen, ground down directly to the level of two thecal series lying in the same plane, and afterwards isolated with acid. It shows the smooth interthecal walls and their straight terminations against the common canal, and also the longitudinal septa. Both the laminæ of the longitudinal septum, which bounds the common canal for the downturned thecal series, which are here not visible, are complete, whilst of the two others only a fragment remains.—Enlarged 6 diameters.

Fig. 8.—Impression of the outer side of two thecal rows lying in the same plane (to the left the anterior right, to the right the posterior left). Between these projects the common canal formed by the longitudinal septa for the thecal series, which are bent downwards and concealed in the rock matrix. The longitudinal septa appear here, as is often the case, to be somewhat irregular, and of a different shape in the longitudinal direction. Transverse sections of the longitudinal septa, therefore, do not maintain the same form throughout the whole length of the polypary. At the proximal end, one side of the sicula embedded in the polypary is free, and its oblique position in relation to the long axis of the polypary is shown. To the right of the sicula the longitudinal septum of the anti-sicula side is perforated by the connecting canal.—Enlarged 4 diameters.

Fig. 9.—Specimen almost completely embedded in the rock, only a small part of the proximal end of the sicula side being free, showing the conical proximal part of the sicula and left theca, the greatest part freed from periderm, so that the partition wall, as well as the connection between the two near the apex, stands out.—Enlarged 6 diameters.

Fig. 10.—A part of a specimen lying in the rock in the same position as the specimen Fig. 8, showing the impression of the proximal part of the anterior right thecal series, and the proximal part of the posterior left series in relief. The substance infilling the sicula has fallen away, except near the apex. To the right of the sicula a trace of the conical elevated part of the left theca, merging into the sicula near the apex.—Enlarged 6 diameters.

Figs. 11, 12.—Transverse section of two different specimens, isolated with acid, showing the commonest forms of the longitudinal septa, the common canal for each thecal series, and the straight inner edge of the interthecal walls.—Enlarged 6 diameters.

Tetragraptus Bigsbyi, Hall.

Figs. 13–16.—A quite uninjured young specimen, representing the *Didymograptus*-stage, showing only the sicula, left and right thecæ, and the connecting canal between them, and at both ends of this its passage into the common canal, which at this stage has the appearance of, and may have functioned as, the distal theca. As in nearly all my specimens of *Tetragraptus*, the apex of the sicula and left theca is somewhat shrivelled. Isolated with acid.—Öland, the cliffs south of Byrum's Sandbay, in the glauconitic grey Vaginatenkalk. Enlarged 12 diameters.

Fig. 13.—From sicula side.

Fig. 14.—From right side. The distal wall of the right theca, not completely developed, forms only a narrow band. Behind the apertural margin of the right theca appears the projection of the sicula. In the interior of the right theca and connecting canal the sicula appears to the left. To the right, on the contrary, the canal is quite open.

Fig. 15.—From anti-sicula side.

Fig. 16.—From left side. The sicula appears here in the interior to the right, the open connecting canal to the left. In the right aperture of the same one gets a glimpse of the undeveloped distal wall of the right theca.

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## II.—Notes on the Diamond-bearing Rock of Kimberley, South Africa. (I) By Sir J. B. Stone, M.P., F.G.S. (II) By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., and Miss C. A. Raisin, B.Sc.

[At the end of last year, while on a visit to Sir J. B. Stone, I had the opportunity of seeing a very interesting series of specimens from the Kimberley mines, which he had obtained during a recent tour in South Africa. Among these were two large lumps of the breccia in which the diamond occurs. As these were in a much better condition for microscopic examination than any which I had ever seen, I asked him to let me study one of them. This request he kindly granted, and sent me samples of all that he had collected. As not very much has been written on the subject, at any rate in the English language,[1] the results of the investigation and the conclusions to which it has led may be worth publishing. At my request, Sir J. B. Stone has contributed, notwithstanding his many duties, a prefatory note on the mines and on the opinion which he formed during his visit.—T. G. B.]

### (I) The Kimberley Diamond Mines, South Africa.

By Sir J. B. Stone, M.P., F.G.S.

IT may be fairly asserted that increased geological interest attaches to the deeper workings of the Kimberley Diamond Mines as they proceed. The remarkable development of underground mining, following upon the amalgamation of interests, which was the outcome of the collapse of the surface workings in 1886, or thereabout, has offered better opportunities for observation, not only of the diamond matrix-material but also of the varying characteristics of the neighbouring rock formations.

The interest created among scientists, upon the first announcement being made that the now famous diamond-bearing "Blue Clay" filled up presumed necks of volcanic craters, has not faded away, nor has the interest in the subject at all lessened. There is, if anything, an increased desire to find out the secret workings of Nature's laboratory, and to learn how the diamonds were formed,

[1] Reasons, in themselves very sad, have hitherto prevented the publication of the elaborate investigations of the late Prof. Carvill Lewis, to which reference has been made below. By a curious coincidence, his manuscripts and all the materials which he had used were entrusted to me by Mrs. Carvill Lewis, just as I had completed my share of the above paper. It is my intention to lose no time in preparing for publication the work of my lamented friend.—T. G. B.

how they came into position, and what is the precise nature of the material in which they are imbedded.

Whilst speculative theories have been propounded, which have added interest to what was already a romantic story, observations have been made at the same time, which are of more exact scientific value and have contributed to a larger knowledge of the subject. Among the facts which have been disclosed are the following: the variation of the character in the diamonds found in the different mines and localities; the varying amount and value of the "stones" from the respective mines, and even from the several parts of the same one; and the variable nature of the "Blue Ground" material.

The diamonds not only occur in all shades of colour, from deep yellow to blue-white, from deep brown to light brown, in green, blue, pink, orange, pure white, and at times even opaque, but also they vary in shape, brilliancy, and size; nevertheless so generally uniform are the particular characteristics of those of any mine, that experts, it is said, can unmistakably distinguish the products of the several workings.

As an illustration, the "stones" from the Jagersfontein Mine are worth thirty or forty per cent. more than those from the De Beers Mine, owing to their purity of colour and brilliancy, though the yield of the latter is evenly about tenfold that of Jagersfontein. Nor is this feature of variation distinguished only in the "stones," for the Blue Clay[1] also varies in its character, it being distinctly different in texture in the several workings; thus, in the De Beers Mine it is so much harder than in the Kimberley Mine, as to take quite twice the length of time to reduce it in the process of disintegration, or, to use a local word, to "pulverize" it, an operation to which all the material is subjected. The yield, too, of diamond wealth is irregular and singularly erratic: the west ends of both the Kimberley and De Beers Mines do not pay to work, whilst the north, south-east, and centres are exceedingly rich, a condition which is even more apparent where the "Blue" lies in close proximity to volcanic rock.

The disintegration of the "Blue" is an interesting process, and throws some light upon the character of the material itself. In past times the same formation, exposed at the surface to the action of the atmosphere, became oxidized and softened, and was always known as Blue Clay, and to-day similar weathering action is relied upon to soften the material which comes from the deep workings in the shape of hard rock. There are thousands of men busily labouring in the labyrinth of galleries below, at varying depths up to 1200 feet, and loads of rock are rapidly sent to the surface, quickly filling long trains of ballast trucks, which are run to the adjacent plains where the wagons are tilted and the precious material is scattered over the ground to undergo the process of weathering; this in the main being all that is needed to disintegrate it, that is if sufficient time is allowed. Violent mechanical means of crushing or breaking up the Blue

[1] This, by the way, is not clay at all when first dislodged in the underground workings, but hard rock, which has had to be "won" by means of drilling and blasting, such as is customary in rock-mining operations.

Ground are necessarily avoided, as it might damage the imbedded diamonds. Therefore weathering action alone is relied upon, subject to the mass being turned over occasionally by "harrowing" it.

The "depositing floors" cover vast areas extending to many square miles of country, which are carefully protected by fences, and the whole vigilantly guarded. The reducing process takes, not merely days or months, but years to bring the material into a condition ready for the work of washing and sorting. At the present time there is a valuable reserve, the worth of which must amount to many years' income; in other words, there are many millions of pounds worth of diamonds stored in these disintegrating areas.[1]

It is not to the purpose here to refer particularly to the process of washing and sorting, or to the thousand and one interesting details that form part of the story of the gigantic and rich enterprises of Kimberley, among which the energy of the De Beers Company takes such a conspicuously leading part, but it is more pertinent to follow the material itself through the series of operations which lead to the final results, and to glean useful geological facts respecting its composition and the history of the diamonds.

The first process of washing carries away all the finer particles of mud, permits the picking out of larger "stones," of easily recognized volcanic rock, or of similar substances, and leaves a mass of granular material from the size of a pin's head to that of a small apple, the several substances amongst it being well and distinctly separated. This is now turned over to the sorters, who proceed to riddle it into classified heaps. Those consisting of the greater particles, amongst which the larger and more valuable stones may be expected to be found, are placed in the hands of confidential and responsible Europeans; the finest, from which the most minute diamonds are extracted, being examined by Kaffirs (all of whom are carefully watched), who go over the fine refuse almost grain by grain.

These granular masses in process of sorting are highly interesting. They are rich in garnets, in olivine, in pyrites, and many other minerals; and they disclose the detailed composition of the breccia of the "Blue Clay."

Among this composite material the diamonds are found in the proportion of about 1 to $1\frac{1}{2}$ carats to the ton, and in size, from the smallest grain to "stones" of the greatest value.[2]

A parcel of diamonds in the rough (such as, for instance, the day's product of one of the mines) is an extremely interesting subject of investigation and study. Such a bowl full of stones, amounting to thousands of pounds in value, fresh from the cleaning process of having been boiled in acids, present in their uncut and unassorted condition a general resemblance to a handful

[1] A better idea of the riches of the mines will be gleaned from the brief statement which has just publicly appeared (July, 1895), that the De Beers Company have sold the output for the year for the sum of three million and a half pounds sterling.

[2] One in the possession of the De Beers Company weighed in the rough state as much as 428 carats.

of saltpetre crystals. A more minute and careful examination discloses the interesting fact that many, if not most of the stones, are fractured, and are but parts of perfect crystals. This indicates that they have been subjected to mechanical forces, explosive or otherwise, and of itself seems to prove that the diamonds were not formed at the spot where they were found.

It should be stated that above the diamond-bearing rocks there are extensive beds of carbonaceous shales, and it has been supposed that chemical action, due to steam generated in the volcanic rock, formed the diamonds.[1] Of course due weight must be given to the facts adduced by those who favour the idea that the diamonds were actually formed at or near the spot where they were found, particularly the one singular fact of the prevailing similarity of stones in localities, which it is admitted remains at present unexplained; but even if the broken diamonds were not sufficient evidence, certainly the schistose surfaces of the "snake" (a hard intrusive porphyritic rock), and the glossy appearance of the crater face lying in contact with the Blue Ground, should be perfectly convincing.

No doubt some such chemical action as indicated did take place and produced the diamonds, but it is more than probable that this occurred far away from their present resting-place, the exuding mud-flow having been propelled forward by earth pressure, or some other dynamical force, and that the diamonds were fractured by extreme pressure in transit.

In conclusion, it is interesting to have to report that the De Beers Company are energetically continuing the work of sinking in the main shaft, which, it may be well to state, is through the adjacent hard rock and within a short distance of the crater funnel of the mine proper. This, to get to the 1200-feet level, has passed through the upper beds of basalt and black shale, through the hard amygdaloidal melaphyre deposit, through some 400 feet of quartzite, and into the lower shale beds.[2]

[1] It may be well here to quote a passage from a letter on this subject received from Mr. W. Moses, the able director of the De Beers Mines, who ventures upon a more elaborate explanation. He says: "I am inclined to stick to my theory of the formation of diamonds and the depositing of them in the present formation of Blue Ground or volcanic mud. To put it as short as possible, the diamonds were produced from carbonic acid gas under extreme pressure and changes of temperature, the oxygen being consumed by the carbon, etc., the result being the diamond. To revert to the present deposits: they were made in the crater of an extinct volcano, into which came thermal springs, which washed away the sides of the soft strata below (the volcanic rocks forming the volcanic mud of the Blue Ground), and the diamonds were introduced from below by the action of the boiling energy of the thermal springs. The blue ground or mud, if you remember, we concluded had not gone under any great heat, as the small particles of shale clearly indicated; in short, the diamonds were separately formed, and were brought into their present position from below." It has also been supposed, and with some show of probability, that with the opportune presence of carbon, under conditions of intense heat and perchance pressure, crystallization took place, the colours of the stones varying as they were affected by the presence of metals or oxides of metals.

[2] A letter recently received from Mr. W. Moses states that "the sinking of our main shaft still continues in the blue metamorphic shale, and no change has yet

## (II) On the Rock and other Specimens from the Kimberley Mines.

By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., and Miss C. A. Raisin, B.Sc.

THE undecomposed rock is obviously a fairly hard breccia, exhibiting a rather irregular fracture and consisting of minerals and rock fragments in a blackish-green, slightly granulated "paste." Some of the minerals, probably fragments, can be readily identified, *e.g.*, olivine, green pyroxene, brown mica, and garnets. The fragments of rock are of various sizes up to about two inches diameter. They are generally rather compact in texture, greenish-grey in colour, sometimes exhibiting a zonal structure near the edges. The specific gravity, determined by a Walker's balance, of a specimen of the breccia measuring about $2\frac{1}{4}'' \times 2'' \times \frac{1}{2}''$ is 2·61; of a piece about one-fourth that volume, 2·66.[1]

Under the microscope the rock is seen to consist of fragments large and small, becoming at last a mere powder, which are set in a serpentinous mineral and a carbonate, these acting as the cementing paste, but the latter mineral being more sporadic in occurrence. Commencing with the larger minerals[2] in the specimen before us, (1) Olivine is the most abundant. Its cleavage in some cases is a little more marked than usual. It occurs generally in rounded grains, partially ringed by serpentine, indeed sometimes completely converted into this mineral. The alteration usually is as follows:—Round each grain is a zone of fibrous serpentine, exhibiting a rather parallel ordering, which acts feebly on polarized light. A zone follows where the fibres are arranged in cones, the apices of which seem to pierce the olivine, as if the cone structure had gradually extended inwards and had affected indirectly that of the whole layer. Here, however, the axes of the cones are more or less parallel. This parallelism seems to depend on some structure in the olivine itself—most probably a cleavage—and not on the form of the grain. In some cases the fibrous mineral seems, from the extinction angle, to be actinolite or tremolite.[3]

(2) Sahlite, or lightish-green augite, occurs in grains often somewhat oblong, commonly with an alteration zone at the exterior, consisting of a fibrous mineral, which has the extinction of actinolite. The olivine and the sahlite often present considerable resemblances in their general microscopic aspect, and the same holds true of their alteration products.

taken place in the appearance of the strata. We have now passed through some 200 feet of this formation, and I am in hopes of getting a change which will be very interesting." Mr. Moses also promises to send a further box of samples when this takes place, which it is needless to say will be of additional interest under the circumstances.

[1] These specimens were given to one of the authors by C. J. Alford, Esq., F.G.S. That brought by Sir J. B. Stone was inconveniently large for weighing.

[2] A number of analyses of minerals are given in the paper by Prof. Maskelyne and Dr. Flight, Quart. Journ. Geol. Soc., vol. xxx, 1874, pp. 408–416. In our specimens, bronzite, which appears to be common in their material, seems to be rare, if not absent.

[3] As was also observed by Prof. Carvill Lewis.

(3) Mica. The flakes are somewhat irregular in outline, of a pale but rather warm brown colour, well cleaved. The pleochroism is from light dull buff to an ochre-brown. Cases of twinning occur; one of the twins sometimes greatly dominating over the other. The mica at its exterior is changed into a mass of a minute, very pale green mineral, which sometimes extends up cleavage cracks. This apparently is the material designated vaalite by Professor Maskelyne.

(4) Garnet: (rare in this specimen) wine-red in colour. In one case this mineral is surrounded by a zone about ·006″ thick (except on one side, where it becomes a mere film). This zone exhibits a radial fibrous crystallization and a banded structure. It varies in colour from a rather light to a very dark umber-brown, and the constituents seem to have a straight extinction. Beyond this, in three directions, is a much broader border, variable in thickness, barely translucent, and a deep umber-brown in colour; but perhaps only a more felted mass of the mineral already mentioned. The more diaphanous part does not appear to be sensibly dichroic, and can hardly be biotite or an altered mica. It might, however, be a mixture of iron oxide with fibrous quartz, as in the so-called crocidolite. In another slice biotite does occur as a decomposition product of a garnet, but here the former mineral eats into the latter in a somewhat irregular manner.

(5) Chromite. Feebly translucent brown grains, occasionally octahedral in form, are doubtless chromite, but other iron oxides are present in the slide.

(6) Pseudobrookite (?). Other brown grains, occurring in a rudely square form or as an association of granules, are anisotropic, and sometimes exhibit, with crossed nicols, specks of rather bright colour, indicative, probably, of aggregate structure. Small crystals, however, of a mineral to be mentioned below (perofskite) are sometimes clustered about these grains and may mask the colour effects. We refer these brown grains to pseudobrookite, though the tint is less rich than usual. This, however, may be due to decomposition.

(7) Rutile. A few small crystals occur, among them a geniculate twin, and in serpentine, as observed by Prof. Carvill Lewis. We doubt, however, whether it is an alteration product.

(8) Perofskite. The grains, usually from ·0002″ to ·0008″, are sometimes hexagonal in outline, often showing a central spot and radial lines, a very faint yellowish tinge with transmitted light, and a whitish or yellowish-grey with reflected. These grains have a habit of clustering, and they sometimes wreathe around fragments of crystals and rocks.

Leaving for a moment the rock fragments, we proceed with the matrix, to which, indeed, the last-named mineral might be referred. Its hardness is barely 3, though among its microscopic constituents is one which scratches glass. When powdered, it effervesces briskly with HCl. Apparently it is composed of the following constituents: (*a*) a clear colourless isotropic serpentine; (*b*) brown mica, in small films, sometimes irregular in outline, having a general resemblance

to that described above, but almost certainly of secondary origin. With mica, perhaps, may be included some rather regular hexagonal thin plates, of an apparently colourless mineral, which seem to project into interspaces; (*c*) chlorite (?); (*d*) needles, often radially tufted, clear and colourless, with low polarization tints and probably straight extinction; (*e*) a carbonate, seemingly varying from calcite to dolomite, filling up interspaces; and probably (*f*) a little opal.

As to the rock fragments, our specimen of the breccia has not afforded either granite or pegmatite, rocks which were detected by Prof. Daubrée. Those present, as described above, have a hardness generally a little less than 4, but one large fragment, paler in colour than most of them, is about 2·5. Under the microscope the outermost zone is usually thin, sometimes consisting rather largely of an aggregate of minute chlorite, followed by a second and broader zone containing films of brown mica[1] with ill-defined outlines; the third zone is often rich in minute perofskite. In other cases the external zone is richer in perofskite, and within this comes a greenish zone, which may be followed by another perofskite band, sometimes broad. The inner part of the fragments is rather "patchy" in structure, consisting, in some cases, very largely of a clear colourless isotropic material (? a hydrous glass). In this, scattered in rather varying quantities, are (*a*) clusters of perofskite; (*b*) films of brown mica (biotite) as above, in one or two cases sprouting inwards from the inner zone; (*c*) minute acicular prisms, giving low polarization tints and straight extinction, often forming tufted or radiating groups (occasionally almost spherulitic), which in a few cases seemingly are growing from the ends of the brown mica; (*d*) rude attempts at skeleton crystals, probably magnetite; (*e*) a carbonate (as in the matrix).

Three fragments differ somewhat from the rest. One includes serpentinized olivine surrounded by a material, which exhibits a structure suggestive of a flowing. Another consists of grains and granules of serpentinized olivine, with thin flakes of brown mica and pseudobrookite or chromite. The third with transmitted light looks almost pellucid, but with crossed nicols exhibits an aggregate structure, such as may be seen in a serpentine, though on a very minute scale, the constituents being grouped in lighter and darker parts, as may be sometimes observed in a scoriaceous rock. One corner, however, exhibits a spherulitic structure, which also makes its appearance here and there in other, commonly the outer, parts of the fragment.

The general aspect of these fragments (except for the zones) recalls certain varieties of much decomposed serpentine, and to this rock, though we have never seen any quite identical, we venture to refer it, believing that it is the result of the alteration of either a glassy or a very minutely crystalline peridotite. The zonal banding may be original, as it recalls that exhibited by fragments in some diabase tuffs from Porthdinlleyn,[2] where it is an original

[1] The biotite is variable in amount, and occasionally is wanting.

[2] *Cf.* C. A. Raisin on Variolite . . . . of the Lleyn: Quart. Journ. Geol. Soc., vol xlix, 1893, p. 151.

structure, such as is common in slaggy ejectamenta. Still, like the bands produced in some stained rocks, it might be a result of infiltration; but though the latter may be a modifying cause, we incline to adopting the former explanation.

The "blue clay" or "blue ground," the material obtained in the earlier and shallower workings, is clearly only a decomposed condition of the rock already described,[1] the cementing carbonate having been more or less removed[2]; and the "yellow ground" represents a further stage in the decomposition. We have compared the fine-grained part of the "blue ground" with some crushed and decomposed serpentine from the Lizard, and find a strong likeness between the dominant material in both, so that very probably the dust-like fragments of serpentine (altered peridotite) enter largely into the composition of the diamantiferous rock. The more durable minerals are separated from it by washing. Two packages, given some time ago to one of us by Prof. Boyd Dawkins, are divided into coarser and finer washings: the former often run from about one- to nearly three-eighths of an inch, the latter do not generally exceed one-tenth of an inch in diameter. The materials appear to be similar, though the relative quantities may differ in the two, and among the coarser some rock fragments (in one case a fine-grained peridotite, in another apparently a sedimentary rock) are present. Among the minerals in these samples, and in those brought by Sir J. B. Stone, which are roughly sorted but are of larger size, we find the following:—

(*a*) Garnets; more than one variety being present. The majority are from a wine-red to a purple-lake in colour (almandine); a few are orange-red to reddish resin-brown, when magnified, (? essonite). They appear to be always fragmental; this is very obvious in the case of the clear-coloured specimens, and even those which are more rounded suggest a fragmental origin. Many of the latter seem to be only dull-coloured greenish grains, but on breaking them they are found to consist of a kernel of red garnet, surrounded by an aggregated doubly-refracting substance. This may be merely some incrusting mineral, but it suggests the possibility of a decomposition zone. Some have on the exterior brown mica, perhaps also a chlorite, with another mineral too minute for identification, and if we may found an inference on the ease with which the grains break, the same material probably occupies fissures.

(*b*) The fragments of sahlite are often determined by cleavage planes. The colour is commonly a fairly rich celandine or oil green, but two or three of the well-rolled small grains are a very rich emerald green. These probably contain a considerable amount of chromium, but we should expect that all would afford traces of this base.

[1] The material which Prof. Maskelyne and Dr. Flight were examining was evidently "blue ground," and was taken from depths not exceeding 180 feet.—Q.J.G.S., vol. xxx, 1874, p. 406.

[2] In the museum at Owens College, Manchester, are some large lumps of partially decomposed breccia intermediate between the ordinary "blue ground" and the specimens described in this paper.

(*c*) Fragments of olivine, of a greenish-yellow colour, not very numerous.

(*d*) Iron oxides. Grains of magnetite are very few in number—not one per cent. of the washing; most of the grains are not attracted by the magnet, have a bright metallic lustre, give a brownish streak, and a bead (with borax) of yellowish bottle-green colour. These are clearly ilmenite, as was further indicated by the usual chemical test. We have not found chromite, but, as our search has not been a very close one, it may have escaped us. It can hardly be common. A good many subrotund grains or little flattish cakes of rusty brown colour prove to be limonite.

(*e*) Occasional grains of pyrite and quartz, and flakes of brownish mica.

Two other rock specimens, brought back by Sir J. B. Stone, must also be noticed. One is a somewhat shapeless lump, with rather rounded surfaces, more or less slicken-sided, unctuous to the touch, and of a pale olive-grey colour. The hardness of the exterior is about 1·5, but a portion of the interior exposed by a fracture is a little less than 3. The former, when powdered, does not effervesce with H Cl, and under the microscope resembles a rather decomposed serpentine; the latter effervesces briskly, and appears to be mainly calcite, perhaps slightly dolomitic. We seem, then, to have a nodule of impure calcite, of what origin it is difficult to say, enclosed in a kind of husk of decomposed serpentinous material.

The other specimen is a hard, fine-grained grit or quartzite, almost black in colour, with a thin banded structure, parallel with which it has a tendency to split, especially where a white mica (fragmental) is abundant. A microscopic section shows it to consist mainly of fragments of quartz, fairly angular to subrotund, a few being compound and possibly derived from veins. The majority contain fluid cavities, although the amount of these is variable; bubbles, frequently small, are generally present, and microlithic enclosures may be occasionally noted. Often there is a thin external zone of secondary quartz. A few fragments of felspar, including a plagioclase, and microcline also occur. The grains are set in an earthy matrix, a good deal of which on close scrutiny has a fragmental aspect, and very probably is largely made up of decomposed felspar. This part, with crossed nicols, is brightly speckled, most likely owing to the formation of a secondary micaceous product. We find also ilmenite, partly converted into leucoxene, a few flakes of altered biotite, and sundry microliths. On one side of the slice are one or two bands of variable thickness, where the rock is darker and more fissile, the fragments being smaller, and the amount of mica (chiefly white) being larger; here also are some grains of pyrite. Probably the rock is a member of the Karoo series, though possibly slightly altered.

Our observations accordingly seem to justify the following statements:—

(1) That the diamantiferous rock is a breccia, which in its unweathered condition is cemented together by secondary minerals.

(2) That it contains various rock fragments, some of them, in all probability, having been formerly peridotites.[1]

(3) That it contains a considerable number of minerals of fair size in a more or less fragmental condition (*e.g.*, olivine, augite, biotite, garnet, magnetite, ilmenite).

(4) That these minerals—or at any rate most of them—are not such as are likely to have been formed *in situ*, but more probably have been obtained by the destruction of rather coarse peridotites, pyroxenites, and eclogites.[2]

(5) That while, since the formation of the breccia, changes to a not inconsiderable extent have taken place in the production of serpentine, chlorite, perofskite, etc., these are not such as are suggestive of a very high temperature or of very great pressure.

We are therefore led to the following conclusions:—That the diamond also was not produced *in situ* in the rock which we have been describing, but, like the garnet, etc., had its origin elsewhere, probably at a distinctly greater depth from the surface.[3] We thus agree with Professor Daubrée,[4] and differ from the views expressed by Mr. Hudleston[5] and Prof. Carvill Lewis,[6] both of whom regarded the diamond as produced *in situ*,[7] but we agree with the former that the "pipes" are probably of volcanic origin,[8] and that heated water

[1] In the specimens which we have examined it happens that fragments of shale, which according to Profs. Daubrée and Carvill Lewis are sometimes abundant, are either extremely small and rare or entirely absent. At any rate, they cannot now be identified with any certainty. [Professor A. H. Green, F.R.S., since these words were written, has most kindly lent me a number of specimens of rocks and minerals which he collected when visiting Kimberley in 1882, together with sundry notes and sections, of great interest. His specimens of "blue ground" are not quite so hard as those described above, but are in better preservation than most that I have examined. They contain fragments of black shale, in one case abundantly. One specimen also includes several angular fragments (up to a good half-inch in diameter) of a compact, slightly streaky, greenish-yellow rock, apparently a rotten serpentine (microscopic examination seems hopeless). There are specimens also of other rocks which occur as fragments in the breccia: three of these must have been of large size; two are amygdaloidal, one a compact diabase, the other a reddish porphyrite; the third an olivine basalt with some flakes of brown mica. Of smaller specimens (not more than about an inch in diameter) six are from the Bloemfontein Mine: one is a diorite, very slightly foliated; the other five are particularly interesting, for they represent a fairly coarse rock, chiefly composed of sahlite and a brownish mica, indistinguishable from that described above in the breccia. There are also specimens of the sheets of doleritic or diabasic rocks of the district. Dykes, sheets, etc., of these, according to Professor Green, are very abundant, as described in his paper (Q.J.G.S., xliv, pp. 254, 264). His sections make the "neck"-like character of the diamantiferous rock very clear —T. G. B.]

[2] As described in our paper, GEOL. MAG. 1891, p. 412.

[3] We may say that this conclusion was arrived at independently of previous writers, for we did not refresh our memory of the opinions expressed by them till our work was practically concluded.

[4] Comptes Rendus, 1890, vol. cx, p. 18.

[5] Proc. Geol. Assoc., viii, p. 65.

[6] Brit. Assoc. Reports, 1886, p. 667; 1887, p. 720; and GEOL. MAG. 1877, pp. 22–24.

[7] Prof. Maskelyne inclines to the opinion that the diamond was produced at or near the contact of a basic igneous rock with a carbonaceous shale, but that since then the whole mass has been affected by mechanical disturbances and thermal waters.—Q.J.G.S., vol. xxx, 1874, pp. 407, 408.

[8] This was Mr. Dunn's opinion, who supposed that the diamond was produced by

has been the principal agent in producing the secondary metamorphism,[1] and we think with the latter that the association of the diamond with a peridotite is not fortuitous, though we believe that this mineral, like the others mentioned above, originated at a much greater depth in the earth's crust. This view, we were glad to find, had already commended itself to Prof. Daubrée, who makes some highly suggestive remarks on the association of diamonds and meteorites.[2]

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## III.—Review of the Evidence for the Animal Nature of Eozoön Canadense.

By Sir William Dawson, C.M.G., LL.D., F.R.S., etc.

### II. Petrological and Chemical.

BEARING in mind the statements made in the previous note, respecting the stratigraphical relations of the Grenville Series, and referring to the excellent account by my friend Dr. Bonney of his observations at Côte St. Pierre, and to some difficulties stated by him which merit attention, we may sum up the evidence so far, under the following statements :—

1. The limestones included in the Grenville Series and their associated quartzites and schists bear so strong a resemblance in mineral character to metamorphosed Palæozoic calcareous beds of organic origin and their associates, as to warrant at least the careful consideration of any forms apparently organic contained in these limestones.

2. The occurrence in these limestones of nodular silicates, of graphite, of pyrite, and of apatite, affords additional reason to suspect their organic origin.

3. The presence of large beds as well as of veins of graphite and of thick deposits of iron ore in the Grenville Series constitutes an additional analogy with Palæozoic formations holding organic remains.[3]

These facts were adduced by Dr. Sterry Hunt and Dr. J. D. Dana in evidence of the probability of life in the Laurentian period, even before the discovery of Eozoön. Certain particulars connected with them, however, now demand somewhat more detailed attention, in connection with that discovery, and with recent objections to the organic nature of Eozoön.

Dolomite or magnesian limestone is a not infrequent associate of Palæozoic fossiliferous limestones; and I have remarked in previous

metamorphism of the carbonaceous material in the shales.—Q.J.G.S., vol. xxx, 1874, p. 54; vol. xxxiii, 1877, p. 879; vol. xxxvii, 1881, p. 609. Prof. Green informs us that his examination led him to the conclusion that the 'pipes' were volcanic necks.

[1] This may have been the last stage in a series of volcanic disturbances, of which the flows noticed by Prof. Green (*loc. cit.*) may have been the earliest.

[2] *Loc. cit.*, pp. 20-24. Prof. Lewis had already called attention to certain points of likeness in the diamantiferous rock and meteorites.

[3] See papers by the author on the Graphite and Phosphates of the Laurentian Rocks, Quart. Journ. Geol. Soc. London, 1869 and 1876.

papers on the similarity of the mode of occurrence of silicified Stromatoporæ in the great dolomite of the Niagara formation with that of Eozoön in the Grenville Limestone, in which dolomite occurs in beds, in thin layers, and in disseminated crystals, in a manner to show that it was an original constituent of the deposit. Dolomite is also one of the most common minerals filling the cavities of Eozoön, and especially the finer tubuli. The mode of its occurrence on the small scale may be seen in the following description of a section of a portion of a bed of limestone from Côte St. Pierre, examined under a lens, after being treated with dilute acid. The specimen comprised about six inches of the thickness of the bed:—

Crystalline limestone with crystals of dolomite, constituting about one half (fragments of Eozoön in calcite portion).[1]

More finely crystalline limestone, with rounded granules of serpentine, some of them apparently moulded in cavities of Archæospherinæ, or of chamberlets of Eozoön.

Limestone with dolomite as above, but including a thin layer of limestone with granules of serpentine.

Limestone and dolomite, with a few grains of serpentine and fragments of Eozoön.

Crystalline dolomite with a few fragments of Eozoön, as limestone, with canals in dolomite.

Limestone with fragments of Eozoön, granules of serpentine, and groups of chamberlets filled with serpentine.

We have thus a bed of limestone in which dolomitic and serpentinous layers appear to alternate, and occasional fragments of Eozoön occur in both, while the smaller forms resembling fossils are, so far as can be observed, limited to the serpentinous layers.

At Aruprion on the Ottawa a portion of the Grenville Limestone presents dark graphitic layers parallel to the bedding, and giving it a banded grey and white appearance which has led to its use as a marble. An analysis by Dr. Harrington shows that the graphitic layers contain 8·32 per cent. of magnesia, the lighter layers only 2·57 per cent., in the state of grains or crystals of dolomite. Associated with the marble there are also beds of brown-weathering dolomite, affording 42·10 of magnesia. The graphite in this marble, under the microscope appears as fibrils and groups of minute clots, and sometimes coats the surfaces of crystals or fragments of calcite, the appearances being not unlike those seen in carbonaceous and bituminous limestones of later date.

In both the above cases the magnesium carbonate is evidently an original ingredient of the bed, and cannot have been introduced by any metamorphic action. It must be explicable by the causes which produce dolomite in more recent limestones.

Dana has thrown light on these by his observations on the occurrence of dolomite in the elevated coral island of Matea in Polynesia,[2] under circumstances which show that it was formed

[1] Distinguished by their fine granular texture and canal-systems.

[2] "Corals and Coral Islands," p. 356, etc.

in the lagoon of an ancient coral atoll, while he finds that coral and coral sands of the same elevated reef contain very little magnesia. He concludes that the introduction of magnesia into the consolidating under-water coral sand or mud has apparently taken place—"(1) In sea-water at the ordinary temperature; and (2) without the agency of any other mineral water except that of the ocean"; but the sand and mud were those of a lagoon in which the saline matter was in process of concentration by evaporation under the solar heat. Klement has more recently taken up this fact in the way of experiment, and finds that, while in the case of ordinary calcite this action is slow and imperfect, with the aragonite which constitutes the calcareous framework of certain corals, and at temperatures of 60° or over, it is very rapid and complete, producing a mixture of calcium and magnesium carbonates, from which a pure dolomite more or less mixed with calcite may subsequently result.[1]

I regard these observations as of the utmost importance in reference to the relations of dolomite with fossiliferous limestones, and especially with those of the Grenville Series. The waters of the Laurentian ocean must have been much richer in salts of magnesium than those of the present seas, and the temperature was probably higher, so that chemical changes now proceeding in limited lagoons might have occurred over much larger areas. If at that time there were, as in later periods, calcareous organisms composed of aragonite, these may have been destroyed by conversion into dolomite, while others more resisting were preserved, just as a modern *Polytrema* or *Balanus* might remain, when a coral to which it might be attached would be dolomitized. This would account for the persistence of Eozoön and its fragments, when other organisms may have perished, and also for the frequent filling of the canals and tubuli with the magnesian carbonate.

The question now arises as to the mineralization of Eozoön with serpentine, and more rarely, especially in the case of its larger and lower chambers, with pyroxene. Connected with this is the alternation, as above described, of serpentinous and dolomitic layers in the limestone, as if in successive times the conditions were alternately favourable to the deposition of magnesium in the form of carbonate and in that of silicate.

We learn from the "Challenger" Reports that under certain circumstances the presence of organic matter in oceanic deposits causes an alkaline condition, tending to the solution of silica and the formation of silicates. We also learn that siliceous matter in a state of fine division (*e.g.* volcanic dust) may afford material for the production of hydrous silicates, either directly or indirectly through the agency of organisms forming siliceous skeletons. The "Challenger" Reports also show that the silicates known under the name of glauconite, and thus deposited, contain several bases to some extent interchangeable. Of these the principal are aluminium, potash, and iron, though magnesia is also present. Some older

[1] Bulletin Geol. Soc. Belgium, vol. ix (1895, p. 3). Also notice in GEOL. MAG., July 1895, p. 329.

silicates injecting fossils in the Palæozoic rocks are less complicated, and contain more magnesia; and, as Hunt has shown, there is nothing anomalous in the supposition that in the Laurentian period silicate of magnesium and iron may have acted in this capacity.[1]

It is true that serpentine is now usually regarded as a product of the hydration of olivine and pyroxene; still, even on this supposition, it might be formed from the hydration of fine volcanic dust falling into the sea. Hunt also has shown that the serpentine of the Grenville Limestone differs chemically from those supposed to be of direct igneous origin in its comparative freedom from iron oxide, in its larger proportion of water, and in its lower specific gravity, besides being a more pure silicate of magnesium. That it can be deposited by water is shown by the chrysotile filling veins, and by my own observations, published long ago, on the serpentine replacing and filling cavities of Cambro-Silurian fossils at Melbourne in Canada, and filling the cells of Silurian corals at Lake Chebogamong.[2]

The occurrence of pyroxene in the limestone, and filling some of the chambers of Eozoön, may also be easily explained. Dr. Bonney well remarks that it does not resemble any igneous rock known to him, and it is quite certain from its mode of occurrence that it cannot be directly igneous. Somewhat thick and continuous beds of a coarser pyroxenite occur in some parts of the Grenville Series, *e.g.* at Templeton, and I have described them as probably volcanic ash-beds, while the large pyroxene crystals found in the veins of apatite traversing these beds are probably of thermo-aqueous origin. But the limited and irregular masses and concretions of white pyroxene occurring in the limestones are of different texture and colour, and more purely silicates of lime and magnesia. They may have resulted from local showers of volcanic ashes drifted by currents into hollows of the Eozoön reefs, and sufficiently fine to fill the larger chambers of dead specimens, and when consolidated to form a basis for the growth of new individuals. This is, I think, the only supposition on which they can be explained, and it would also explain the difficulty suggested by Dr. Bonney as to the association of the pyroxene with Eozoön.

There seems, however, to be no good evidence that any portion of the pyroxene has been changed into serpentine; and it is evident that if such a change had occurred after the consolidation of the rock, serious chemical and mechanical difficulties would be involved, whereas if volcanic débris, whether of the nature of olivine or pyroxene, became hydrated while the rock was incoherent and in process of formation, this would tend greatly to promote the infiltration with hydrous silicates of any fossils present in the mass.

Assuming the serpentine and pyroxene to have been deposited as

[1] See Analyses of Glauconites, etc., by Dr. Hunt in "Dawn of Life," p. 126. One tertiary example is silicate of iron and magnesia. See also Hoskins on Glauconite, Geol. Mag., July 1895.

[2] Quart. Journ. Geol. Soc. 1864, p. 69, also 1879, p. 48 *et seq.*, Memoir on Eozoön in Peter Redpath Museum, 1888, p. 48 *et seq.*

above suggested, the remaining objections stated by Dr. Bonney would at once disappear. Specimens of Eozoön or other fossils might be infiltrated or filled with these silicates, and while the latter were superabundant they might form separate concretions or grains which might in some cases envelop the fossils or be attached to them in irregular forms, just as one finds in the case of the flints in chalk or the chert in some other limestones.[1]

It is scarcely necessary to say that no objection to the organic origin of the Eozoön can be founded on the fact that many of the specimens are fractured, crushed, bent, or faulted, by the movement of the containing rock, or on the circumstance that well-preserved specimens should be rare, and found chiefly in beds containing silicates capable of injecting their cavities. On the other hand, the circumstance that fragments of Eozoön are abundant in the limestone is one of the best possible proofs that we are dealing with a calcareous organism. It would be interesting to describe and figure a number of specimens in our collections illustrating these points; but to do so would require an extensive illustrated memoir, for which neither space nor means are at present available.

I observe, in conclusion of this part of the subject, that in any highly crystalline limestone we can hope to find well-preserved fossils only when their cavities and pores have been filled with some enduring siliceous mineral; but, on the other hand, that porous fossils, once so infiltrated, become imperishable. It still remains to consider shortly new facts bearing on the structure of Eozoön and its possible biological affinities.

(*Part III will appear in the December Number.*)

## IV.—On the Stratigraphy of the Crag of Suffolk, with especial reference to the Distribution of the Foraminifera.[2]

By H. W. Burrows, A.R.I.B.A., etc.

THE successional order of the strata of the Crag of the Eastern Counties, and the grouping and relationship of the several members of this formation, are here described more especially with regard to the Foraminifera obtained from them. These remarks on the distribution of the Microzoa in the Crag are based upon the examination of material collected by myself during the past eight years, with the exception of some from Tattingstone and Gedgrave (zone *g*) kindly supplied by Professor Prestwich. The whole of this material has been worked over by Mr. Richard Holland and myself; and Mr. Frederick Chapman has given us some aid with the Tattingstone Crag. Whilst assisting lately in the production of Part II of the Monograph of the Foraminifera of the

[1] It is a curious coincidence that Dr. Johnston-Lavis has described in the July Number of this Journal, the aqueous deposition at ordinary temperature of crystals of pyroxene and hornblende, in cavities and crevices of bones included in an ash-bed of recent date, and in presence of calcite, apatite, and fluoride of calcium, as in the Grenville Series. This is a modern instance analogous to that suggested above.

[2] Read before Section C of the British Association at Ipswich, Sept. 12th, 1895.

Crag, it has been necessary to re-examine the collections previously made by the late Messrs. S. V. Wood and W. K. Parker, and the work done by them, with Dr. H. B. Brady and Professor T. Rupert Jones; and in view of the desirability of having the latest information in a tangible shape, I have been led to put together some notes on the Crag and the Distribution of its Foraminifera for this Monograph, Part II. An Abstract of my memoir is now offered to the British Association, meeting at Ipswich in the centre of the Crag district.

The relative abundance of the Bryozoan, Molluscan, and other remains, besides the Foraminifera, is necessarily an important element in the classification of the Crag beds, and is taken into careful consideration.

The Pliocene beds of the British Isles have been exhaustively dealt with by Prof. Prestwich (1841–1890), and lately by Clement Reid in his "Pliocene deposits of Britain" (Memoirs Geol. Survey, 1890); and the foreign equivalents are tabulated in G. F. Harris's Appendix to R. B. Newton's "Syst. List of F. E. Edwards's Coll. British Oligocene and Eocene Mollusca, British Museum," 1891.

## PLIOCENE FORMATION.

### A. Newer Pliocene Beds (Upper Crag).

I. *Beds above the Red Crag* (Norwich Crag, etc.).—From Southwold there were enumerated ten species of Foraminifera in the First Part of the Monograph;

From Thorpe, near Norwich, seven species;

From Bramerton, two species;

From the Chillesford beds, eight species are known.

These are common forms of *Textilaria*, *Bulimina*, *Lagena*, *Nodosaria*, *Polymorphina*, *Truncatulina*, and *Polystomella*; mostly of North-Atlantic habitat.

II. *Red Crag* (Essex and Suffolk).—The coarse quartzose sand and ferruginous condition of the Red Crag were not favourable to the presence and preservation of Foraminifera; but a more extended research in the finer and lighter-coloured sands might prove profitable, although a prolonged search through some of the grey sand, so rich in Mollusca, from Walton-on-the-Naze, has not resulted in any additions to the twenty species recorded in the Monograph, Part I, 1866, Table in Appendix II.

### B. Older Pliocene (Lower Crag).

I. *St. Erth Beds.*—At St. Erth, near Marazion, Cornwall, occurs a very small outlier of sands and clays, the Pliocene age of which was definitely established by the late Mr. S. V. Wood, jun. (1885); and a full description of the exposure was given by Messrs. P. F. Kendall and R. G. Bell (1886), and by Mr. C. Reid (1890).

Beneath the vegetable soil and "head" (argillaceous deposit with angular stones), are sand and clay, and then a *fossiliferous* blue clay ($1\frac{1}{2}$ to 3 feet thick), underlaid by a pebble-bed and sands: all are variable, but amount to 12–14 feet in thickness. The Foraminifera

have been carefully worked out by Mr. Fortescue W. Millett, of Marazion; and the lists published by him (1885, 1886, 1894) give a total of 163 species and well-marked varieties. Of this number seventy-six are also met with in the Coralline Crag; and the additions now made to the rhizopodal fauna of the latter emphasize the similarity to a considerable degree.

The present notes have special reference to the Crag of the Eastern Counties; and, although the St. Erth beds are of great interest, they are only thus briefly referred to for the purpose of comparison. They contain a very rich assemblage of *Lagenæ* (thirty-six species); while only twenty-three are recorded from the Coralline Crag, of which, however, eighteen are common to the two. One of the most interesting is *Lagena seminuda*, Brady, a species met with at only six stations by the "Challenger," two in the South Atlantic and four in the South Pacific, with a range of depth from 1300 to 2350 fathoms. In the St. Erth clay it is rare; but in the Coralline Crag (zone *f*) it is rather common; so that we have in the Pliocene beds the earlier appearance of a comparatively shallow-water form, which has apparently since migrated to deeper seas. The *Polymorphinæ*, so well represented in the Coralline Crag, appear to be somewhat rare at St. Erth; but of the fifteen recorded species, ten are also found in the former. Taken altogether, the balance of evidence, so far as the Foraminifera are concerned, supports the arguments adduced by Mr. C. Reid for including the St. Erth beds with the Older Pliocene.

II. *Coralline Crag* (termed also the "Suffolk Crag," "White Crag," "Bryozoan or Polyzoan Crag").—Both by Prof. Prestwich (1871), and by Messrs. S. V. Wood, jun., and F. W. Harmer (1872), two main divisions of this Crag were fully recognized. The upper division (zones *h* and *g*), 36 feet thick; and lower division (zones *f* to *a*), 47 feet, altogether 83 feet, according to Prestwich; and the whole (zones 3‴, 3″, and 3′) 60 feet by the other authors.

1. At *Sutton* and *Ramsholt* zones *a*, *b*, *c*, and part of zone *d*, are developed.

The lowest zones were exposed only in long since disused pits. The old pit on Mr. Colchester's farm at Sutton, south side of Sutton Farm Hill, showed in 1860 (Prestwich): Under the surface soil (1 foot); zones *d* and *c*, 17 feet, the latter rich in Foraminifera; zone *b*, 4 feet; zone *a*, phosphatic nodules, mammalian remains, and foreign boulders (Nodule bed), 1 foot, on London Clay. The Ramsholt pit was correlated with part of zone *c*.

2. At *Broom Hill*; zones *d* and *c*. Pit near the Keeper's Lodge, one mile west of Orford Church: Under the surface soil and drift (3 feet); zone *e*, 7 feet; *d*, 15 feet, probably lenticular, not exceeding 10 to 12 feet in thickness in 1894.

Foraminifera are abundant in both zones in this section. In zone *d*, in addition to the forms common to most of the Coralline Crag exposures, *Polystomella crispa* is perhaps the most common, together with fine specimens of *P. macella*. Some of the *Polymorphinæ*, as *P. frondiformis*, *P. complanata*, *P. compressa*, and *P. gibba*,

are very large and well grown; and the same remark applies to *Pulvinulina repanda*. *Cassidulina lævigata*, not usually a common form in the Coralline Crag, is also fairly plentiful in this zone. In zone *e* we notice the same abundance of *Polystomella crispa*, large and well developed. Other common species are *Textilaria sagittula*, *Truncatulina lobatula*, *T. Haidingeri*, and *Rotalia Beccarii*. On the other hand, *Nonioninæ* are rare and small. Milioline forms are remarkably absent.

3. *Sudbourne Hall.*—Under the surface soil and drift (1½ feet); zone *d*, 6½ feet.

This pit is referred, somewhat doubtfully, by Prof. Prestwich to the zone *d*; but the Mollusca, especially the band with *Arctica islandica*, in a greenish to buff-coloured Crag, so distinctive of this zone at Broom Hill, Sutton, and elsewhere, together with the Foraminifera, confirm this view. Some of the latter are here very fine; specimens of *Polymorphina frondiformis* 5 mm. long, and of *P. complanata* 4 mm. long, are not uncommon. *Polymorphina variata* is also plentiful and well grown, together with *Textilaria agglutinans* (varieties) and *T. trochus*.

4. *Tattingstone* (*Park Farm*); zone *d*.—Prof. Prestwich kindly supplied some material from the outlier of Coralline Crag occurring in this locality, four and a half miles south-south-west of Ipswich. The section is now much overgrown; but originally, beneath 12 feet of Red Crag, about 8 feet of Coralline Crag were exposed. This was referred with some doubt by Prof. Prestwich to his zone *d*; and the foraminiferal fauna differs somewhat from that referable to this zone in other localities. *Lagenæ* are fairly plentiful; *L. lacunata* and *L. melo*, not often met with elsewhere, being rather common. Excepting some species which range through the entire formation, Foraminifera are rather rare.

5. *Sutton*; zones *e*, *f*, and *g*.—The pits in this classical locality are now somewhat obscured, weathered, and overgrown. The celebrated Bullock-yard pit, about 250 yards south-west of Pettistree Hall, furnished the late Mr. S. V. Wood with the bulk of his extensive collection of Mollusca from this formation. In 1894 a comparatively fresh excavation, some forty to fifty yards north of the Bullock-yard pit and facing Pettistree Hall, showed: Under the surface-soil (2 feet); zone *g*, 2 to 3 feet; zone *f*, 5 feet; zone *e*, 4½ feet. The strata are in all probability lenticular and unevenly bedded. Here the zones *e* and *f* have yielded a rich foraminiferal fauna. The latter gives *Polymorphina frondiformis*, *P. variata*, *P. gibba*, *P. complanata*, *P. communis*, *Textilaria gibbosa*, *Biloculina ringens*, etc.; while the *Lagenæ*, rarer as individuals, are numerous in species. *Dentalina pauperata*, 6 mm. long, *D. obliqua*, 7 mm. long, *Polymorphina nodosaria*, 4 mm. long, and *Dimorphina tuberosa*, 4 mm. long, are not infrequent. In zone *e* the species common in the same zone at Broom Hill are also plentiful here; and *Nonionina scapha*, rather rare there, is very common here and well developed. *Miliolinæ* are rather common, together with *Planorbulina Mediterranensis* and *Discorbina rosacea*.

It seems probable that the greater number of the species recorded from Sutton in the First Part of the Monograph of the Foraminifera of the Crag (1866) were from zone *f*; but, if that were not so, it is now impossible to separate those found in zone *e*.

6. *Gedgrave.*—Zones *f*, *g*, and *h* are still well shown in the pits at High and Low Gedgrave, one-and-a-half miles west of Orford.

Pit close to *High House, Gedgrave.* Under the surface soil, zone *h*, 2 to 3 feet; zone *g*, for about 17 feet to bottom of the pit; base not seen.

Pit at *Low Farm, Gedgrave*, close to the marshes, showing in part the downward succession of the High House Pit; zone *f*, 6½ to 7 feet (base not seen). A small pit at *Ferry Barn*, half-a-mile to the south-west, also shows a good exposure of this bed, with Foraminifera and small Mollusca.

Zone *f* is rich in Foraminifera, some being large and striking, *e.g. Textilaria agglutinans, T. gibbosa, Polymorphina variata, P. frondiformis, P. compressa, P. complanata*, together with large, but rarer, *Biloculina ringens*, etc. *Spirillina vivipara*, usually a rare species, is somewhat common here. Speaking generally, the Foraminifera are closely allied to those from Sutton, zone *f*.

In zone *g* a striking feature is the comparative abundance of *Lagenæ*, particularly the marginate forms. Other rather common species are—*Nonionina scapha, Spirillina vivipara, Miliolina oblonga, Planorbulina Mediterranensis, Textilaria sagittula, Bolivina Ænariensis*, and *Rotalia Beccarii*.

Zone *h* has probably been reconstructed from a part of zone *g*.

7. *Aldborough*; zone *g*.—The pits near the Red House, Leiston Road, close to Aldborough, show about eight feet of fine, buff-coloured, rubbly limestone full of Bryozoa, in part decalcified. Mollusca are not abundant, those species of which the tests are formed of aragonite having been removed by percolation of carbonated waters. *Chlamys opercularis* is abundant, however, as the shell consists of calcite. Owing to this decalcification, Foraminifera are somewhat scarce in this locality, only a few much decomposed Porcellaneous forms, such as *Miliolina oblonga, M. seminulum*, and *Biloculina ringens*, occurring. The Hyaline forms, although better preserved, are usually in a somewhat decomposed condition, with the chambering obscured. Thus probably the original foraminiferal fauna is by no means fully represented.

8. *Sudbourne.*—Pits to the north-east of Sudbourne Church. The upper beds in this neighbourhood are nearly all referable to zone *g*; they are very ferruginous, and the Foraminifera badly preserved. Eleven species, mostly common elsewhere, have been found; they are plentiful, but obscured with iron-oxide.

III. *Lenham Beds.*—The sands and fossiliferous ironstone found at Lenham, in Kent, by Professor T. Rupert Jones and Mr. W. Harris, were referred in 1858 by Professor Prestwich to the Crag and Diestian Series; and this has been confirmed by further comparison of the fossils with those of Diestian age. These sands do not appear to have been examined for Foraminifera, and probably

decalcification would cause a false conception to be taken of the protozoan life.

IV. The *Nodule Bed*; zone *a*, originally exposed at Sutton (see above).—In the exposures now open, as at Foxhall, the mixed and remanié character of the deposit precludes any trustworthy inferences being made from such specimens as might be found.

*Note.*—Some Foraminifera derived from much older Tertiary beds were found by Mr. Searles V. Wood in the Coralline Crag of Sutton and elsewhere, namely, *Orbitolites, Orbiculina, Alveolina, Peneroplis, Amphistegina, Nummulites,* and *Orbitoides*; mostly unique specimens.

The value of Foraminifera as a means of establishing stratigraphical correlation, with few notable exceptions, such as *Nummulites* and *Fusulina,* has not perhaps been so fully recognized as it might be.

In the Coralline Crag the most strikingly constant Foraminifer is *Polymorphina frondiformis*, and this species appears to be characteristic of this horizon in England. So far as I am aware, it is not met with in the Antwerp Crag. I have collected and examined material from the Casterlian and Scaldisian of the Kattendyk Docks, but have not found this species; nor is it recorded from the Diestian. May this not prove that the Antwerp beds are of somewhat different age to those of England?

The "constancy and determinability" of the zones established by Professor Prestwich for the Coralline Crag were doubted by Messrs. S. V. Wood, jun., and F. W. Harmer; but the foregoing notes tend to prove that there is good ground for accepting his subdivisions. The exact correlation of isolated patches of the Crag is not in all cases easily established; and further research is needed to finally settle the relationship of some of them.

So far as my researches on the Mollusca of the Crag have extended, and I have collected for several years from almost every exposure now open, they confirm the zonal arrangement of the beds. The band with *Arctica islandica* is apparently constant to zone *d*. At Sutton and Gedgrave, points widely separated in the Crag area, zone *f* is characterized by the relative abundance of species which are either absent or rare in other zones; among such may be named *Bullinella acuminata, B. conulus, Adeorbis subcarinatus, A. pulchralis, Trochus obconicus, Raphitoma brachystoma, Turbonilla elegantior, Lima ovata,* and others; while some species, though not so distinctive of this zone, are far more abundant than in any other, such as *Ringicula buccinea, Cæcum mammillatum, Triforis perversa, Astarte Forbesi,* and other species.

## NOTICES OF MEMOIRS.

SNOW DUST. By Prof. CLEVELAND ABBE. *Monthly Weather Review,* January, 1895, pp. 15–19. (U.S. Weather Bureau.)

ON the night of January 11–12, 1895, a shower of dust in connection with snow fell throughout a large part of Indiana and Kentucky. The dust may have been intermingled with snow in

the air, or may have fallen with the wind that preceded a second snowfall. At any rate, it was found afterwards forming a layer of dirty snow, between two clean layers of snow, and it was thus easy to gather it free from the underlying soil. A large number of specimens were collected and were submitted to microscopical and physical examination. The dust was found to be largely made up of silt, mixed with organic matter, and was probably derived from some dried-up lake, pond, or marsh to the north-west. Professor Whitney's mechanical analysis shows that it is almost identical with the loess that covers great areas in Illinois, Nebraska, and other adjoining States, and he gives the following Table showing the percentage by weight of the contents of air-dried samples:—

| | Moisture. | Organic matter. | Medium sand, 0·50—0·25 mm. | Fine sand, 0·25—0·10 mm. | Very fine sand, 0·10—0·05 mm. | Silt, 0·05—0·01 mm. | Fine silt, 0·010—0·0005 mm. | Clay, 0·005—0·0001 mm. |
|---|---|---|---|---|---|---|---|---|
| Rockville, Ind., black snow ... ... ... | 3·17 | 11·98 | 0·00 | 0·00 | 0·00 | 69·37 | 5·80 | 9·68 |
| Virginia City, Ill., upland loess... ... | ... | ... | 0·00 | 0·01 | 7·68 | 61·85 | 9·60 | 15·15 |
| Virginia City, Ill., valley loess ... ... | ... | ... | 0·01 | 0·10 | 24·84 | 60·98 | 2·80 | 6·15 |
| Nebraska loess formation ... ... ... | 5·40 | 4·96 | 0·00 | 0·00 | 23·14 | 54·81 | 2·46 | 9·45 |

The different estimates of the amount of dust that fell vary from $12\frac{3}{4}$ to 150 lbs. avoirdupois per acre. C. Davison.

## REVIEWS.

I.—Chemical Crystallography. An Introduction to Chemical Crystallography. By Andreas Fock, Ph.D. (Berlin). Translated and edited by William J. Pope. (189 and xvi pages, 8vo.) Clarendon Press, Oxford.

MASKELYNE'S "Morphology of Crystals" has been quickly followed by a companion volume issued from the same Press, and dealing, not with the geometrical form, but with the origin, growth, and chemistry of crystals. In a review of the former book it was stated that Crystallography has now developed relationships with other sciences, by which it is invested with numerous practical applications. Fock's little book should be read by every chemist or geologist who wishes to have a thoroughly lucid and reliable account of the manner in which crystallography dovetails into chemistry, and especially of the remarkable problems which have emerged into prominence during the last few years in the region of physical chemistry. Some of these have come into existence

since the date of the German edition, and account for the large amount of additional matter which appears in the English translation.

Osmotic pressure, diffusion, the nature of double salts and isomorphous mixtures, the equilibrium between different substances in a mixed solution—all these are subjects of vital importance to the chemist, and of no less interest to the geologist who occupies himself with the study of igneous magmas. Important above all is the experimental work of Roozeboom upon the last-mentioned problem. About a third of the book is devoted to a sketch of isomorphism, under which these points are ably treated. There is, of course, mixed with established facts much that is hypothetical, and little attempt is made by Dr. Fock to sift the one from the other; but he has, at any rate, given a truthful abstract of work which was previously only to be found dispersed through many books and journals.

Mr. Pope has made an excellent translation, and has done good work in bringing the subject to the notice of English readers. The result of his collaboration with Dr. Fock has been to supply a thoroughly attractive and readable survey of all that is known at the present date about chemical crystallography or crystallographic chemistry.

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II.—An Introduction to the Study of Rocks. By L. Fletcher, F.R.S., etc., Mineral Department, British Museum (Natural History). Printed by Order of the Trustees: London. 8vo, pp. 118. Price 6*d*.

THIS Handbook may well be considered alongside of the Guide to the Collections of Rocks and Fossils belonging to the Geological Survey of Ireland.[1] Both in a measure show the difficulties of grouping information which relates to diverse specimens arranged in cases; but the methods adopted in the two works are in many respects widely different. In the Survey Guide, the age, method of formation, and life-history of the rocks are dominant features; in the British Museum Guide, greater prominence is given to their mineral structure and characters.

Commencing with definitions of different kinds of rock and of large mineral masses, the author proceeds to describe their varieties of structure and composition, and the methods of crystalline growth. In reference to characters he uses the term *petrical* for those to be observed in large rock-masses in the field; and *lithical* for the characters manifested by fragments of rocks, such as are preserved in a museum. Then follow concise and excellent explanations of many terms commonly used to describe these various characters.

The variations in rock-masses and the similarities between rocks of different ages are duly noted; and it is pointed out that the same mass may at one age belong to one kind, at another age to a different kind of rock, as a result of metamorphism. Serpentine is cited as an example.

The author then expresses his determination "that rocks should

[1] *Infra*, p. 516.

be distributed into kinds by means of lithical characters alone," and states that these may be grouped in regard to Mineral composition and Structure. He takes thirty different rocks, and seeks to ascertain how they may be classified. Seven preliminary groups are first made, but they lead to assemblages which are more curious than instructive. Thus, among "Rocks essentially composed of material belonging to a single mineral species," we find Rock-salt, Quartz-rock, Limestone, and Serpentine grouped together; and again, among "Rocks which, though really composed of material not belonging to a single definite mineral species, are so far homogeneous in aspect that the essentiality of the compositeness is concealed from the unaided eye," we find Coal, Clay, Obsidian, Phonolite, and Felstone arranged together. We may, indeed, question the value of such temporary assortments. It is as if we arranged the books in a library according to their bindings; and the author himself proceeds to show that any arrangement based on apparent simplicity is unsatisfactory for purposes of classification. He then discusses the modes of origin of the rocks belonging to his seven preliminary groups, and also the processes by which the rocks have attained their present characters. This leads to certain re-arrangements in his groupings, and to a number of separate descriptions of the principal rocks. Hence the student must turn from page to page if he wants to learn all that is said about crystalline schist, gneiss, slate, shale, or any other rock. The index will here prove very serviceable, but we venture to hope that in the future editions of his work the author may find ways of simplifying his groupings and descriptions of rocks. He has devoted great care and pains to his work, he has given us much valuable and precise information, and has pointed out a number of ways in which rocks may be arranged; but we believe the student would have found the path to knowledge easier if one general classification had been given, and if the descriptions of each type of rock had been in sequence.

Like all the British Museum publications, this work is excellently printed, and in respect both to type and paper it sets an example that might well be followed by Her Majesty's Stationery Office. Its price is sixpence.

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III.—Petrology for Students: An Introduction to the Study of Rocks under the Microscope. By Alfred Harker, M.A., F.G.S. (Cambridge, at the University Press).

THIS is a book which presents no easy task to the reviewer; it is so full of thorough and useful work and so carefully put together that there is practically nothing in it to correct and little to add, while to endeavour to make an abstract of it would be to make an extract of Liebig or to compress pemmican. Avoiding the long description of the petrological microscope which usually occupies so many of the first pages in a book of this kind, referring to other special works for descriptions of minerals, and laying aside any digression on methods of research other than study in the field, with the lens, and with the microscope, the author plunges

at once into his subject and teaches us just exactly what we want to know about the shape, appearance, and general optical characters to be observed in the microscopic study of minerals, and of the rocks which they constitute. Then with a few passing words on classification he begins his description of Plutonic rocks with the Granites.

He divides the igneous rocks into three broad classes, of which the plutonic class needs no explanation; the intrusive rocks are defined as "certain families of rocks" which "are met with almost exclusively in the form of dykes, sills, laccolites of small dimensions, and 'pipes' of old volcanoes"; and the volcanic rocks are those which "have consolidated from fusion under superficial conditions, *i.e.* by comparatively rapid cooling under low pressure."

An uniform mode of description is adopted throughout. After a few preliminary remarks on each great rock-group we are given a list of the constituent minerals and their characters in the rocks in question, an account of the structure of the rocks, of their leading types, and, where necessary, of their special modifications. The leading types, whenever possible, are defined from British examples, but where the British Isles fail to supply the desired information the whole world is laid under contribution. The especial value of this part, and indeed of the entire work, is that the description is written in almost all cases direct from the actual specimens, and the author tells us with reserve of particulars and variations which have not come within the wide range of his own personal observation. Notwithstanding this, very full references are given throughout, and this will make the book especially valuable to the advanced student, as it gives him a mine of bibliographic detail.

A slight slip occurs under the Diorites, where the rocks of Nuneaton are stated to be probably of Carboniferous age. As a matter of fact these diorites, like the Cambrian sediments into which they are intruded, are unconformably overlain by Carboniferous rocks, and are almost certainly not later than Ordovician in point of date. Where similar rocks occur, as at Inchnadamff, the Wrekin, and the Longmynd, they penetrate Cambrian or older rocks only, and have never been found to touch Ordovician strata.

The term Gabbro is not used quite in the sense suggested by Teall, but appears to be confined to rocks possessing the diallagic modification of augite. Two main types of ultrabasic rocks are recognized, the picrites and the peridotites, the former "having usually subordinate plagioclase," the latter being non-felspathic. In dealing with the basic intrusive rocks Mr. Harker departs from the usual, and, as we venture to think, the best, practice of British petrologists in declining to use the term diabase for the altered representatives of the dolerite family, and in applying it to ophitic and granulitic rocks which "are holocrystalline and typically non-porphyritic." Thus the word dolerite is reserved to designate volcanic rocks of basaltic composition in which the distinction between phenocrysts and ground-mass is not well marked. By

such use of terms we find the Ordovician sills of Carnarvonshire, the Whin Sill, and the Clee Hill rock named diabases, but when we look for dolerites amongst the volcanic subdivision we find the term not very decisively defined and applied to only two rock-groups, those known as Toadstones in Derbyshire and the ophitic and granulitic rocks of the Inner Hebrides.

It is interesting to notice that the criterion of age is once and for all swept away in naming volcanic rocks, and the author uses such terms as rhyolite, trachyte, and basalt for volcanic rocks of Tertiary and pre-Tertiary ages.

Sedimentary rocks are dealt with in considerable detail under the usual headings, and we would call especial attention to the full and accurate treatment of the calcareous division, which includes an account of the microscopic appearance of the chief organic constituents of these rocks.

The last but by no means least important part of the work is devoted to the consideration of metamorphism, beginning with a masterly account of the minerals developed by thermal action in various kinds of rocks, igneous, sedimentary, and even foliated. Dynamic metamorphism is also ably treated, a distinction being drawn so far as possible between the direct effects of pressure and movement and the secondary effects due to heat liberated by crushing and shearing. A lumber room has still to be provided for the reception of "various crystalline rocks," including schists, gneisses, granulites, and eclogites; some of these are shown to be due to thermal metamorphism, others to dynamic action on sedimentary or igneous material, and the rest are probably original igneous products.

The Pitt Press is to be congratulated on the printing and appearance of the book, and the proof-sheets have evidently been read with extreme care; but it is a great pity that the drawings, on which much labour has clearly been spent, presumably by the author, have not been reproduced by some more satisfactory process, which would have dealt more tenderly with the minuter details in them.

In closing the book we have only two words to add to the student, be he field-worker, petrologist, or mineralogist—*Read it.*

W. W. W.

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IV.—Guide to the Collections of Rocks and Fossils belonging to the Geological Survey of Ireland. By A. McHenry, M.R.I.A., and W. W. Watts, M.A., F.G.S. 8vo, pp. 155. (Dublin: Printed for Her Majesty's Stationery Office by Alexander Thom and Co., 1895. Price 9*d.*)

THE collections of rocks and fossils belonging to the Geological Survey of Ireland are deposited in the Science and Art Museum at Dublin. Commenced when Jukes was Director of that Survey, the collections of late years have been much amplified, so that they are well calculated to illustrate the general geology of Ireland. The original collection was fully described in a catalogue prepared by Jukes, and all the facts of importance published therein have been incorporated in the present volume. Moreover, the works of the

many geologists (whether connected with the Survey or not) who have made a study of Irish Geology, have been consulted in the preparation of the Guide, so that it aims to give a summary of all the leading facts connected with the subject. That this aim has been fully and most carefully carried out, will be acknowledged by all who peruse the work of Messrs. McHenry and Watts.

At the same time it will be freely conceded, that it is almost impossible to produce a work that will readily serve all the wants of those who have access to the Dublin Collection, and of those who seek only to learn the latest results of enquiry relating to the Geology of Ireland. To get a connected account of each formation we have to look under four headings devoted to each province, and there is no index to facilitate reference. With patience, however, the student will be able to glean what he wants; and the entire work contains such valuable records of fact and so many lucid explanations and suggestions (all for the small sum of ninepence!), that it should be in the hands of every working geologist.

The rocks, stratified and igneous, are described in four great groups, those of Leinster, Connaught, Ulster, and Munster. The following are the formations described:—

| | |
|---|---|
| Recent | Blown Sands, Alluvium, Peat, etc. |
| Pleistocene | Glacial Drifts. |
| Pliocene | ("Manure Gravels" of Wexford.) |
| Eocene or Oligocene | Upper Basalts.<br>Leaf Beds, etc.<br>Lower Basalts. |
| Cretaceous | Chalk.<br>Upper Greensand. |
| Jurassic | Lias. |
| Triassic | Rhætic Beds.<br>Keuper.<br>Bunter. |
| Permian | |
| Carboniferous | Coal-measures.<br>Millstone Grit.<br>Yoredale Series.<br>Carboniferous Limestone.<br>Lower Carboniferous (Slate, Sandstone, etc.). |
| Old Red Sandstone | Upper.<br>Lower (including Dingle Beds). |
| Upper Silurian | Ludlow<br>Wenlock.<br>Tarannon.<br>Llandovery. |
| Lower Silurian | Caradoc-Bala.<br>Llandeilo. |
| Cambrian | |
| Foliated Crystalline Rocks. | |

We observe a certain amount of reticence in assigning any particular age (even a pre-Cambrian age) to the several areas of crystalline schists: and there is justification for caution. While Kinahan, in 1878, remarked that "Rocks older than the Cambrian formation are not known in Ireland"; Hull, in 1891, observed that "Recent investigations have conclusively established the existence, in several detached areas, of representatives of these [Archæan] the most ancient of known rock-groups."

In the present work the authors include under the general heading of "Foliated Crystalline Rocks," granites that in places graduate into gneisses, various schists, micaceous limestones, and grits, all more or less sheared and foliated. Some of the quartz-schists are very like that group known in the Scottish Highlands as "moyne-schist"; but the only area referred to as Archæan is that of Pettigo, in Donegal, where the hornblendic and granulitic gneisses are grouped with the "old gneiss" of the north-west Highlands. While some of the gneisses are foliated granites, others appear to be altered grits; and with regard to age, the fact is that the complex masses of older plutonic and metamorphic rocks have not yet been fully investigated. Limestones yielding forms referred with some doubt to Corals, occur interbedded with the quartzites and schists in Donegal; and certain shales at Fintown, in Ulster, which occur in association with foliated rocks, have yielded markings like Graptolites. Hence it is as yet impossible to say what infoldings of altered sedimentary and fossiliferous strata may occur amid older and perhaps pre-Cambrian crystalline schists.

No traces of the old trilobite-faunas of the Cambrian rocks have yet been discovered. These rocks in Ireland have only yielded few and doubtful fossils; but the problematical forms named *Oldhamia* are regarded as of "probably organic origin."

In the Silurian rocks the task of following out the zones indicated by Graptolites, has borne good fruit, and the results at present attained by the Geological Survey are duly indicated. Palæontological evidence has thus been obtained to enable more definite correlations to be made with the English and Welsh divisions of the Silurian system.

The Dingle Beds and Glengarriff grits are grouped with the Lower division of the Old Red Sandstone, and this is conformable to the Upper Silurian; while the Upper Old Red Sandstone (Yellow Sandstone Series) passes up conformably into the Carboniferous rocks.

In ascertaining what has been done with regard to the Lower Carboniferous rocks, and their relationship with the Upper Devonian, we should have been glad of the names of some of the common and characteristic species. As it is, genera only are mentioned, and the vexed subject of correlation is not discussed.

Of the newer formations but little need here be said; it is interesting, however, to note that the "Manure Gravels" of Wexford are considered to be of Pliocene date, though newer than the St. Erth Beds.

The Igneous rocks are arranged so as to give the student a history of volcanic action in Ireland from the earliest times to the great eruptions of Tertiary date. Particular accounts are given of the contemporaneous or interbedded volcanic rocks that lie amid the Foliated Crystalline rocks, the Lower and Upper Silurian, the Old Red Sandstone, Carboniferous, and Lower Tertiary; and of the intrusive rocks which penetrate all formations up to the Lower Tertiary. A great many eruptive rocks have for the first time been examined in detail and described, while some of them have proved

new to Ireland. Contact-metamorphism is illustrated by the effects produced on all types of sediments by the intrusive dolerites of Antrim.

The section on Fossils contains a useful general account of each great division of Plants and Animals, and a summary of the leading fossils of each group of strata. This is followed by a list, with references, of the figured and type specimens of fossils in the Survey Collection. A brief account is also given of drawings, photographs, maps, and sections that are preserved in the Museum; and the work concludes with an index (under numbers) of the places from which the rock-specimens described in the Guide have been collected.

V.—Geological Papers by Edmund Garwood, M.A., F.G.S., in Vols. I and II of "A History of Northumberland," issued under the direction of the Northumberland County History Committee, and Edited by Edward Bateson, B.A. (Newcastle-upon-Tyne and London, 1893–1895.)

I SHOULD like to draw the attention of geologists, and more especially of those among them who are interested in North-Country Geology, to a series of papers by Mr. Edmund Garwood which, unless they are historians and archæologists as well as geologists, they run the risk of missing altogether.

To antiquarians it is well known that a very elaborate History of Northumberland, on a very large scale, is in course of publication by a learned committee having the seat of its operations at Newcastle-upon-Tyne. Of this great work, two superb quarto volumes of the ten or dozen intended have already been issued to subscribers, and it is much to be feared that many who would wish to keep abreast of the progress of British geology may be unaware that, buried in the mass of topographical, chronological, and genealogical details which necessarily make up the bulk of the work, there are a number of valuable geological chapters—much too valuable to be overlooked without loss.

The scheme of this "History" is, unfortunately, such that the chapters in question are not consecutive, and refer each one to a particular parish or group of parishes, sometimes anything but adjacent. This naturally leads to a considerable amount of repetition, the disadvantage of which is perhaps to some extent counterbalanced by a certain convenience for local purposes which may be conceded to the plan. This criticism apart—and Mr. Garwood is in nowise responsible for the lines on which he has been forced to work—nothing but praise can be meted out to these useful and, in several cases, important additions to Northumbrian geology.

The papers are distributed as follows:—

Vol. I. The Geology of Bamburghshire, pp. 3–9; The Geology of Bamburgh Parish, pp. 13–17; The Geology of Belford Chapelry, pp. 357–362. Appendix I. References to Geological Papers, pp. 417. 418.

Vol. II. The Geology of Embleton Parish, pp. 2–8; The Geology of Ellingham Parish, pp. 217–221; The Geology of Howick, Long

Houghton, and Lesbury, pp. 328–336. Appendix I. References to Geological Papers (continued), p. 496. Appendix II. Sections of Coal Workings in the Mountain Limestone Formation, pp. 497, 498. Appendix III. View of Cullernose Bay, showing junction of the Whin Sill and Sedimentary Rocks (an excellent Photographic Plate). Appendix IV. Coloured Plate, giving the details of the Section from Howick to Cullernose Point. Appendix V. Plate of Sections, showing sedimentary rocks associated with the Whin at Ratcheugh, Little Mill, and the Harkess Rocks, (after Tate and Lebour).

It will be seen from the above list that a great deal of ground has been covered by Mr. Garwood, and it should be added that he has spared neither time nor trouble in carefully going over every inch of it. Though thoroughly master of all that had been previously done in the districts described, the author has used his own judgment in all cases, and has added largely to the facts already recorded concerning them. More particularly I would call attention to his interesting discoveries respecting the minerals resulting from contact-metamorphism in connexion with the Great Whin Sill, to what is probably a raised beach noticed by him on the Howick coast, and to his very pertinent and suggestive remarks respecting the Drift deposits that form a marked feature in much of the country referred to. His work is in no sense a compilation, though he has in every instance endeavoured to do full justice to previous observers, but is the result of honest hard work such as any field-geologist would be proud of. Under these circumstances one cannot but regret that the form of its publication should be likely to withdraw it from the recognition which it deserves.

I may perhaps express a hope that when the series of papers is completed they may be issued separately, and thus rendered accessible (which at present they certainly are not) to ordinary geological readers. G. A. Lebour.

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VI.—The Rubble-drift and Ossiferous Breccia in the Island of Palmaria, and on the Shores of the Gulf of Spezzia. By Professor Giovanni Capellini. (Mem. R. Accad. Sci. Istit. Bologna; ser. 5, vol. iv, 1895.)

In this memoir reference is first of all made to Professor Prestwich's various papers on the Rubble-drift and Raised Beaches of Southern England and the Northern Coast of France, in the Journal of the Geological Society of London and the Reports of the British Association, in 1861–65. Professor Capellini then alludes to the deductions drawn from a consideration of this particular Drift, especially as seen at Brighton and Sangatte, and given in the Bulletin Soc. Géol. France, 1880; and to the conclusions arrived at by Prestwich, as published in the Philosophical Transactions, in the Journal of the Geological Society, and Proceedings of the Victoria Institute; and of late published in a separate book treating of the "Tradition of the Flood." These are to the effect that at the above-mentioned places, and elsewhere in Western Europe, the peculiar Drift treated of bears direct evidence of a great submergence,

followed by an upheaval of the land, at the close of the Glacial period.

Reviewing the observations formerly made by Pareto, De la Marmora, himself, and others at places on the Italian coast and islands, Prof. Capellini gives the result of his visits to the cave called Cala Grande, in Palmaria, meeting with the characteristic Rubble-drift strongly developed. He adds some interesting details of the discoveries made of late years in the breccia at the Grotta dei Colombi, between the headlands of Pittonetto and Capo dell' Isola, in Palmaria.

In 1863 Prof. Capellini had seen this Rubble-drift lying on the local limestone, as a coarse breccia of limestones, jaspers, etc., at Calandrella, between Pertusola and Santa Teresa; but had regarded it as belonging to the Triassic. Also other coarse breccia near Santa Teresa, Pitelli, and Santa Terenzo. These corrections will be made in the explanation of the geological map of the environs of Spezzia.

On the east side of the Gulf of Spezzia he has defined the limits and height of the Rubble-drift, in connection with the small masses of ossiferous breccia of Monte Rocchetta; and he finds that it covers the highest parts of the Isle of Palmaria or southern extremity of the west side of the Gulf. The range on the east side was probably submerged for more than 200 mètres of its present height at the end of the Palæolithic period.

Much is to be expected from a close examination of this Rubble-drift on the Italian coasts and islands, in connection with the numerous caves and bone-bearing breccias. Prof. Capellini fully adopts Prestwich's views as to the nature and origin of the Rubble-drift; and points out that it is probably the same singular deposit of which several geologists have noticed traces on the coasts of the Mediterranean, and of which Professor Issel (treating of the Raised Beach between Arenzano and Cogoleto) has well remarked that "one could include it neither among the alluviums, nor among the marine Quaternary deposits."

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VII.—A Geological Enquiry respecting the Water-bearing Strata of the Country around London. By Joseph Prestwich, F.G.S., etc. 8vo. (London: Gurney and Jackson, 1851–1895.)

AT the time of the first publication of this work, the Lower Greensand was regarded as underlying London, and as a possible source of water-supply. Subsequently, however, the deep boring by the New River Company at Camden Town proved the contrary. A large plate accompanied a partial issue of this book, but was accidentally destroyed, and the rest of the printed sheets remained on hand. Since that time it has been proved that the Palæozoic ridge beneath London is limited in its extent both eastwards and westwards; and that the outcrop of the Lower Greensand is wide enough to receive sufficient rainfall to allow of its yielding a good water-supply. On the west, favourable localities are near Leatherhead and Windsor, and in the Godalming and Hindhead district as

originally stated; and on the east, in the neighbourhood of Shoreham, Strood, Frindsbury, and Loughton. Hence the re-issue of this useful work, with its woodcuts (without the original plate), and with additions by the author, Professor Prestwich, D.C.L., F.R.S., etc.

VIII.—The Climates of the Geological Past and their Relation to the Evolution of the Sun. By Eug. Dubois. 8vo, pp. 167. (London: Swan Sonnenschein and Co., 1895. Price 3*s.* 6*d.*)

THIS interesting and suggestive little volume is worth reading, even though geologists may not be prepared to accept the author's conclusions. Leaving out of account subsidiary questions, his argument is mainly this:—Starting with the accepted hypothesis of a cooling sun, he suggests, from a comparison of the relative number of fixed stars in each class, that there is probably a rapid transition from the "white" or hottest to the "yellow" or second stage, and a more gradual transition to the "red" or coolest stage. He then alludes to the evidence of long-continued genial conditions in the earth's climate, extending apparently with little change from Carboniferous to Cretaceous times. This genial and almost changeless period he correlates with the "white" stage of the sun's history—when the sun was comparable to Sirius or Regulus in the light and heat he gave out. Then, arguing from the scarcity of transition stars between the white and yellow class, he thinks that there came a rapid change to the yellow, or Capella, stage, and a great fall in the heat radiated by the sun; this period of rapid refrigeration being represented by the Tertiary period, with its fast diminishing temperature. At the beginning of Pleistocene times the yellow stage was reached, and a series of Glacial and inter-Glacial epochs set in, corresponding with oscillations of the sun between the "yellow" and the "red" or coolest stage. It is for the astronomer and physicist to criticize these speculations; but to the mere geologist it seems as if the author were hurrying things on rather too fast, if we must accept so vast a change in the condition of the sun as having occurred during the small portion of geological time that extends from the commencement of the Tertiary period to the present day.

For a second edition it would be well to have the proofs examined by an Englishman. The translation is usually well done; but one occasionally comes across German or Dutch idioms which, not having the original by us, are not easy to comprehend. Among the plants mentioned we find "Cornelian" (for Cornel) and "wolfs' claws" (given as a living plant allied to *Lepidodendron*).

IX.—Fauna Fosil de la Sierra de Catorce, San Luis Potosi, por Antonio del Castillo y Jose G. Aguilera. Boletin de la Comision Geológica de México. No. 1. (Mexico, 1895.)

The Fossil Fauna of the Sierra of Catorce, in San Luis Potosi, Mexico. 4to, pp. ix and 55, pls. i–xxiv.

THE Sierra of Catorce is a comparatively isolated ridge, about 10 leagues in length and 2 in breadth, with a plateau-like

summit, which is elevated 1200 metres above the plains of San Luis. It is a well-known mining area. The Sierra consists of three principal rock divisions: the lowest is formed of altered shales or phyllites, in which no fossils have as yet been discovered; the second division, which is rich in fossils, is built up of arenaceous and marly shales; whilst the upper division consists of a shaly lower portion, and over this compact gray limestones with nodules and bands of chert or flint. This upper division contains species of *Exogyra*, *Lucina*, *Phylloceras*, and *Schloenbachia*, which are considered by the authors to represent the Aptian and Albian stages of the Lower Cretaceous.

The main purpose of this memoir is the description of the fossils of the second division, which are regarded as in part of Jurassic age, and in part Cretaceous. The authors subdivide the formation into higher and lower groups. The higher, or Cieneguita, is of shales and sandy marls, more or less calcareous, which contain no fewer than nine species and varieties of *Aucella*, together with *Lytoceras*, sp.n., *Placenticeras*, sp.n., *Pulchellia*, sp.n., and *Olcostephanus*, sp.n. The most important and numerous of these fossils are the various species of bivalve mollusca of the genus *Aucella* which are intermingled in the different strata of this subdivision, the thickness of which altogether does not exceed five metres, whilst in Russia five of these same species, according to Lahusen, characterize as many different zones of the Upper and Lower Volgian! As the Mexican Beds contain as well a form of *Olcostephanus*, which is nearly identical with *O. Asterianus*, D'Orbigny, from the Neocomian, and a species of *Pulchellia*, a genus exclusively Lower Cretaceous, the author thinks that the higher group with *Aucella* should be regarded as Neocomian.

The lower subdivision, or the Alamitos group, consists of fine-grained sands and argillaceous shales. It contains *Rhynchonella*, 2 sp., *Terebratula*, 2 sp., *Waldheimia*, sp.n., *Aucella Bronni*, *Cucullæa*, sp.n., *Lucina*, 2 sp.n., *Cyprina*, sp.n., *Cyprimeria*, sp.n., *Goniomya*, sp.n., *Pleuromya*, sp.n., *Vermetus*? sp.n., *Nautilus*, sp.n., *Rhacophyllites*, 3 sp.n., *Haploceras*, 3 sp.n., *Perisphinctes*, 16 species, of which 12 are new, *Olcostephanus*, sp., *Hoplites*, 4 sp.n., *Aspidoceras*, sp.n., *Aptychus*, 2 sp., and *Belemnites*, 2 sp. Reviewing the affinities of the various forms in this group, it is placed as Upper Jurassic, probably on the horizon of the Kimeridge and Portland Beds.

The descriptions of the fossils in this memoir appear to have been carefully drawn up, but the figures are not sufficiently clear to allow of any safe judgment to be formed as to the characters of the species they are intended to represent. This is the more unfortunate since such a large proportion, more particularly of the Ammonites, are described as new. As regards these latter, it may be remarked that in no single instance are the suture-lines figured, and as they are only referred to in one or two cases, it may be supposed that they are not shown in the type-specimens. Again, it would be impossible to discriminate from the figures the various species of *Aucella*, and unless the originals show the specific characters clearer

than the figures, not much weight will be placed on the remarkable statements as to the distribution of these forms in the Mexican beds as compared with those in Russia.

This memoir is an important contribution to the Geology of Mexico, and it may be hoped that it is the first of a series which will make known the geological characters of that country in detail.

G. J. H.

## CORRESPONDENCE.

### REPLY TO PROFESSOR HULL ON THE GLACIAL DEPOSITS OF ABERDEENSHIRE.

Sir,—Anything Prof. Hull writes is sure of respectful attention in many quarters—not least in that part of the West of Scotland where he laboured during an early stage of his geological career, and where he still has some good friends. From the lettered retreat in which he fitly "crowns a youth of labour with an age of ease," the Professor emerges (in your last Number) to rebuke and exhort a "neo-glacialist" for his errors and "fanciful views" regarding non-submergence and the Glacial period. May the heretic be allowed a few words by way of reply?

The Glacial deposits of Aberdeenshire consist, it may be repeated, of the following, in ascending, *i.e.* chronological, order:—

1. Lower Grey Boulder-clay, derived from the rocks of the district.
2. Beds of Gravel and Sand, with water-worn pebbles and fragments of shells.
3. Upper Red Clay, with boulders and a few marine forms.

No. 1 is admitted to be the *moraine profonde* of an ice-sheet which once extended seaward from the mountainous region on the west. The only questions are regarding 2 and 3. Under what conditions were they formed? Do they indicate submergence up to, or somewhat beyond, the highest level at which they are found? Or are they also due—under certain changing conditions—to land-ice? The answers to these questions are various:—

Dr. Jamieson says No. 2 *does not*, but No. 3 *does* indicate submergence.

The Geological Surveyors say No. 2 *does*, but No. 3 *does not*.

Professor Hull says *both do*.

The only other possible view is also held, viz. that *neither* indicates submergence.

Now, as Dandie Dinmont used to observe, "that makes an unco difference"; and in such a divided, not to say disorderly, state of opinion on the subject, it seems hardly fair to say, or imply, that anyone trying to throw additional light upon it is animated by an "innate love of change."

After laying down the grand "rational" rule or principle that "deposits differing in composition and structure from each other should have been formed under different sets of conditions," Prof. Hull goes on to state the "evident succession of conditions" of these three differing superimposed deposits in Aberdeenshire, viz.:

1. "General land glaciation" (admitted).
2. "Submergence in sea-waters" (?).
3. "Continued submergence" (!).

These are the "different sets of conditions" for the "diversified forms" of deposits 2 and 3! Of course, Prof. Hull may explain that other conditions, which may vary, are included under "submergence"; but if so, he must allow glacialists, "neo-" or otherwise, to say the same (with as much, or they may think, *more* reason) of "glaciation."

We shall look at these other conditions immediately. Meantime it seems almost sufficient to remark that Prof. Hull has first of all to settle matters with Dr. Jamieson. That careful observer concluded from his study of the materials of these deposits (2 and 3) that both had been transported by northward-moving land-ice. Prof. Hull seems to overlook entirely the essential facts which led Dr. Jamieson to this conclusion. These are: *first*, the presence in both deposits of stones foreign to the district, and not found even in the Grey Till underneath, but, particularly in No. 3, clearly derived from tracts to the south; *secondly*, striations on rock-surfaces confirming this, showing first a local glaciation from the west, followed by a more general one from the south; and *lastly*, the fact that the shelly fragments in No. 2 were largely of *Crag* species—pre-Glacial forms—which Dr. Jamieson accounted for by inferring that the northward-moving ice had "scoured out" some area of the *Crag* along the coast, and conveyed the materials to some extent northward and inland in its progress. All this Prof. Hull overlooks. The result is striking. A deposit containing fragments of Pliocene or pre-Glacial shells and pieces of "yellow limestone and calcareous shale not now found *in situ* in Aberdeenshire," is supposed to be due simply to an inter-Glacial submergence!—after the country had been swept by a "great ice-sheet," in whose *moraine profonde* no trace of such rocks or organisms can be found!

Thus it becomes evident that the other conditions which Prof. Hull adds to submergence, even if granted, will not account for the deposits in question. "Sand and gravel brought down by rivers from the adjoining emergent lands" could not contain fragments of rocks not found there either *in situ* or in fragments, and of which there is no evidence that they have ever been there. Then Prof. Hull supposes that the "continued submergence" was accompanied by "the recurrence of cold conditions"—rather a violent supposition, for the obvious natural tendency of submergence (in this part of the world, at least) would be in the opposite direction, towards *milder* conditions of climate.[1] But granting the supposition for a moment, it is clear that "glaciers occupying the higher elevations" could not produce a "Red Clay" totally unlike the waste of the rocks of the district (as Dr. Jamieson has pointed out), nor mingle that clay with foreign materials, such as "stones of a volcanic nature unlike the rocks of Aberdeenshire or the North of Scotland,"

[1] See this MAGAZINE for Sept., p. 403.

but resembling the masses of trap which occur in the Old Red of Forfar and Kincardine.

In short it appears that the facts of the case, with singular perversity, resist all Prof. Hull's endeavours to place them under the "saut water!"

Passing from this, the Professor makes the following remarkable statement: "I would observe that the ice of the North Sea . . . was only forced over the land while the North Sea was blocked by ice, in which there were neither shells, star-fishes, nor probably seals." Surely Prof. Hull understands that in all such cases the contention is that the ice has transported materials formed in the sea-bed *before* it was so blocked? If he does not believe in such transport, then he has to settle matters with Sir Arch. Geikie, Dr. James Geikie, Messrs. Peach, Horne, De Rance, Clement Reid, Lamplugh, and many others, before condescending to me! Or are they all "neo-glacialists" together, and alike smitten with "the innate love of change"?

The Professor speaks as one standing on the shore of truth, and looking out over a sea of error, of "the confusion which has arisen among the neo-glacialists regarding the glacial phenomena of the British Isles." It seems very evident that the sect or school of geologists referred to (whoever they may be) did not *make* the confusion, but only *found* it.

As Prof. Hull ends by quoting part of a private note from Dr. Joseph Prestwich, I may also close with a sentence from the same high authority—a sentence which may well be taken as a guiding light in all discussions on this subject. In his standard work on "Geology," speaking of those slow movements of the earth's crust, of which the latest evidences are seen in our "Raised Beaches," that distinguished author sums up as follows:—"Continuous for long periods in the earlier times, and productive of settlements to be measured, in Cambrian and Silurian times, by thousands of feet, they have gradually diminished in intensity and power, until, in the later geological times, those great slow continental movements became limited to hundreds, and in more recent times have become reduced to, so to speak, tens of feet, or to a state of comparatively stable equilibrium."—(Vol. ii, p. 525.)

GLASGOW, 9*th October*. DUGALD BELL.

*Postscript*.—I have omitted to notice Prof. Hull's remark on the little sketch map in my paper in the *Quarterly Journal* for August. He says—"On comparing the lines of the ice-movement with the arrows given by Prof. James Geikie in the 'Great Ice Age,' they are almost always at right angles: both cannot be correct." This is very astonishing. I wonder what map Prof. Hull has been looking at? Let the reader judge for himself by turning to the map of the "British Isles during the Epoch of Maximum Glaciation" given by Dr. Geikie at p. 69 of the work referred to. There he will see the lines of ice-movement running up along the Aberdeenshire coast, and curving round to N.W. across the Moray Firth, and over the northern part of Caithness, as I have shown them.[1] Of course it is the recent edition of Dr. Geikie's work that is referred to. Can it be that Prof. Hull

[1] Anyone wishing confirmation of this may also turn to Croll's map of the Ice-Sheet in North-western Europe, in "Climate and Time," or to Sir A. Geikie's map of the glaciation in his well-known "Scenery and Geology of Scotland."

has been founding his remark on the *old map*, in the first or second edition of that work, showing only the earlier glaciation on land, and not at all the subsequent ice-movement along the coast? In any case, as Prof. Hull seems to throw doubt on one's accuracy in the matter, it becomes necessary to point out that the mistake is entirely his own, as doubtless he will readily acknowledge.

## THE AGE OF THE RHYOLITES OF COUNTY ANTRIM.

SIR, — The "Proceedings of the Geologists' Association" for August, 1895 (vol. xiv, p. 152), contain a communication made by myself to Mr. R. Lloyd Praeger respecting the probable contemporaneity of the rhyolites of county Antrim and the granite of the Mourne Mountains. This statement was based on notes made by me early in the year, and I had learned, from conversation with Mr. W. W. Watts, that similar views were current among the members of the staff of the Geological Survey of Ireland. Hence the form in which Mr. Praeger utilized the information sent to him.

I wrote, however, in June, before I had received my copy of the GEOLOGICAL MAGAZINE for that month, and hence Mr. McHenry's clear statement of his belief,[1] though by that time published, was not directly referred to. As soon as I read his paper, I forwarded an account of it, and a withdrawal of any reference to myself, to Mr. Praeger, who revised the amended sentences on his proofs; but the correction appears to have been overlooked in the press of business connected with a summer excursion of the Association. I make this explanation, since the passage, as published in August, is distinctly unfair to Mr. McHenry's paper, which has thrown such light upon the question.

GRENVILLE A. J. COLE.

ROYAL COLLEGE OF SCIENCE FOR IRELAND,
DUBLIN; *October 13th*, 1895.

# OBITUARY.

## ROBERT FITCH, F.S.A., F.G.S.

BORN OCTOBER 21ST, 1802. DIED APRIL 4TH, 1895.

GEOLOGY, like other branches of Natural History, has owed much of its progress to the zeal of collectors. Of these, one of the most painstaking and successful was the late Robert Fitch, who, in addition to a most valuable collection of antiquities, had gathered together a very fine series of fossils from the Crag and Chalk of Norfolk. He was born at Ipswich, on October 21st, 1802, educated at the Grammar School, and apprenticed to a chemist and druggist in the town. Pursuing this occupation he settled in Norwich, in 1827, in partnership with Mr. Sheriff Chambers, and continued until he was over 90 years of age to take an active interest in business. From an early date he took great interest in fossils, and his specimens were always at the service of those engaged in palæontological studies.

He seldom wrote on geological subjects, his chief literary contributions being to the "Transactions of the Norfolk Archæological Society." In 1836, however, he communicated to the Geological Society an account of the discovery of the tooth of a Mastodon in

[1] "On the Age of the Trachytic Rocks of Antrim," GEOL. MAG. 1895, p. 264.